JOURNAL OF THE IRON AND STEEL INSTITUTE

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Telephone : SLOane 0061. Telegrams : Irosamente, Sowest, London

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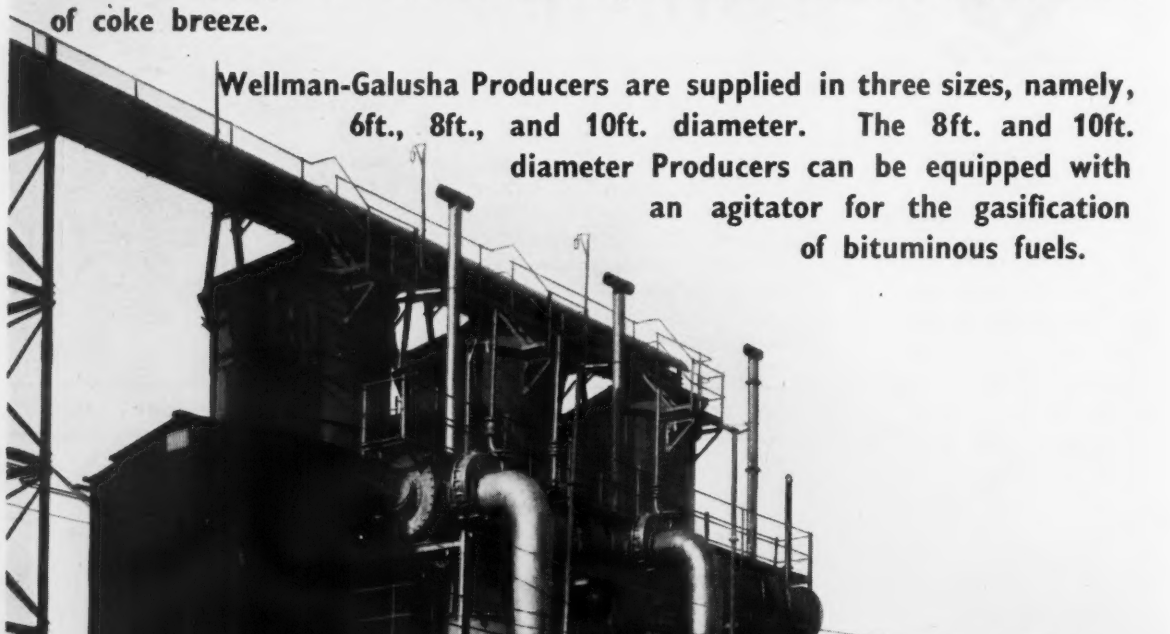

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IRON AND STEEL
INSTITUTE PAPERS

PLANT DESIGN · MANUFACTURE · RESEARCH · DEVELOPMENT

The Smidth Agglomerating Kiln

PLANT AND PRACTICE AT EAST MOORS WORKS, CARDIFF

By W. E. Simons

SYNOPSIS

The rotary kiln provides an alternative method to sintering for the treatment of fine ores and flue dust. The construction of a particular kiln and the layout of the plant are described.

The operating procedure is outlined and details, including analyses, are given of the ingoing materials and of the finished agglomerate ; some of the difficulties and hazards of the process are mentioned. Data are given relating to the use of the agglomerate in the blast-furnace, and the advantages and disadvantages of the rotary kiln are discussed.

THE Smidth rotary kiln described in this paper was installed in 1938 and commenced production in February, 1939. It was designed to use 100% flue dust, of which there were considerable reserves in the district. These stocks have now been consumed and the present practice is to use about 35% flue dust, the balance being fine ore and pyrites. The output of the plant is of the order of 3000 tons of agglomerate per week.

DESCRIPTION OF THE PLANT

General

The plant is housed in two main buildings, one (185 × 75 ft.) containing the stockyard and bunkers, and the other (273 × 35 ft.) accommodating the kiln. The plant is serviced with the necessary railroads. (*See* Fig. 1.)

The raw materials, supplied in box wagons, are dealt with by gravity from three inclined roads converging on to a wagon tippler, and are then tipped into the main stock building or put into the bunkers, as required, by means of a 9-ton overhead crane fitted with a grab.

The four concrete 150-ton capacity bunkers span the width of the stockhouse and are discharged by lamellar apron feeders on to a horizontal rubber conveyor belt, the discharge from each being carefully controlled so as to maintain the required mixture. The control, which is a very flexible one, is obtained by adjustment of a ratchet device and by varying the speed of a 1¾-h.p. motor which drives each apron feeder. Once a certain mixture is set, the total volume of feed to the kiln can be varied from the main control panel simply by altering the speed of the motors, and in practice this is frequently necessary.

The horizontal conveyor belt discharges on to an inclined conveyor belt system, which elevates the feed and delivers it into the kiln through a 1-ft. dia. pipe. A weighing device is incorporated in the system and tests are carried out when necessary.

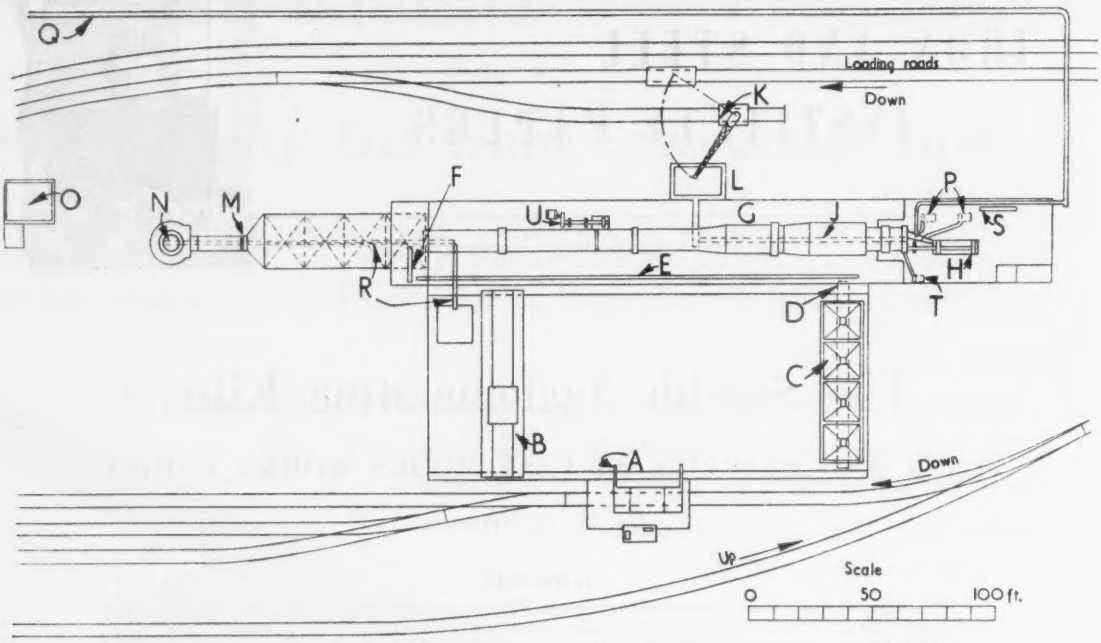
The Kiln

The kiln is made of ¾-in. and 1-in. steel plates; it is cylindrical in design, and is 200 ft. long. It is set at an angle of 4% and is mounted on four sets of steel rollers with brass bearings of the plain self-aligning type, fitted in a water-cooled chock. On the second set of rollers from the feed end are two horizontal jockey wheels to prevent or take any thrust if the kiln moves up or down. Normally, horizontal movement is relatively slight and the kiln floats between the jockey wheels.

A 110-h.p. motor drives the kiln, through totally enclosed double-helical gears, followed by straight-toothed gears engaging with a pinion ; for the final drive on the kiln barrel the spur drive is connected to the kiln by tangential steel leaves to take any shock or distortion. The speed is 1–2 r.p.m., depending on operating conditions.

The kiln is divided into four zones (*see* Fig. 2), known as the barrel, the small zone, the well or big zone, and the sinter zone in which the agglomeration takes place. The dimensions are shown in Fig. 2. Details of the kiln lining are given later.

Manuscript received 13th July, 1950. Mr. Simons is Assistant Blast-Furnace Manager at Messrs. Guest Keen and Baldwins Iron and Steel Co., Ltd., East Moors Works, Cardiff.



A — Tipper
B — Grab crane
C — Feed bins
D, E, F Conveyor belts or band conveyors
G — Kiln
H — Scraper car
J — Cooler conveyor
K — Steam crane
L — Loading pit
M — Damper
N — Chimney
O — Substation
P — Fans
Q — Gas main
R — Drag chains
S — Control panel
T — Sealing-ring air fan
U — Kiln motor and gearing

Fig. 1—Plan of agglomeration plant

Removal of Waste Gases and Dust

At the feed end of the kiln an orifice plate is attached to restrict the waste-gas exit, the actual outlet diameter being 4 ft. 2 in., and through this the feed pipe is set at an angle. The waste gases pass through a large concrete smoke chamber to a chimney 195 ft. high, and between them is the chimney damper, controlled from the burner's platform. The damper opening in the stack is 7 ft. 3 in. high and 6 ft. 5 in. wide.

The base of the smoke chamber is divided into eight hoppers from which the deposited dust discharges into a gas-tight trough extending under the chimney, and into which a hopper fitted under the chimney empties. The small quantity of dust in this trough is cleared by drag chains and is conveyed into the stockhouse for re-use. The joint between the kiln and the smoke chamber is sealed and is made gas-tight with a large ring of asbestos cord.

Figure 3 shows the dust chamber, chimney, and long drag chain.

Discharge of Agglomerate : the Kiln Hood

The discharge end of the kiln rotates in a fixed bricklined hood. At this end of the kiln there is an angle ring around the steel plates to which is bolted a circular casting known as the foundation ring. Bolted to the other end of this ring are 10 segmental heat-resisting castings, constituting the extreme end of the kiln. The top of the foundation ring and part

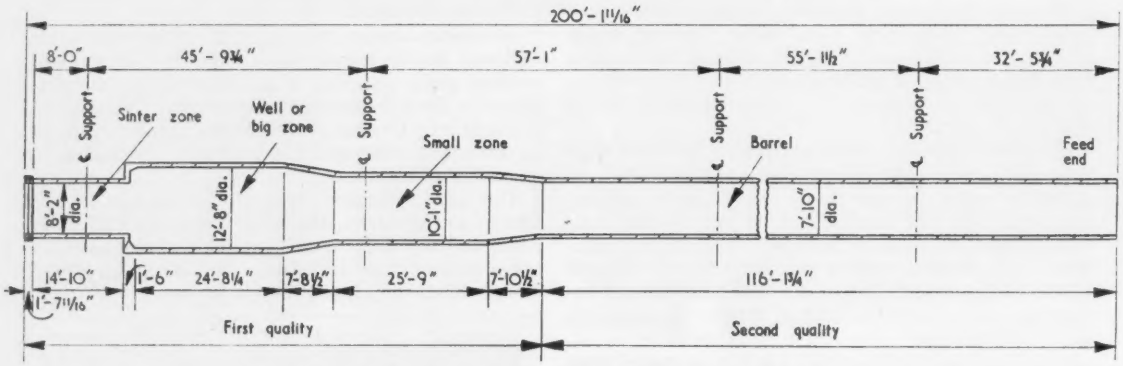


Fig. 2—Section through kiln, showing brick lining

of the castings are overlaid with brickwork. To prevent excess heating, a small current of air supplied by an independent fan is blown on to the foundation ring, which itself is covered by the kiln hood. The bottom part of the hood consists of steel-plate water coolers arranged to form a hopper through which the finished agglomerate passes down a water-cooled chute on to the cooler conveyor. This is a lamellar-type conveyor, 80 ft. long, consisting of steel castings 24 in. wide, and passes through a bricklined tunnel running directly under the kiln. The agglomerate falls from the cooler down a chute into a pit outside the building and is subsequently loaded by a steam grab crane into hoppers. The discharge end of the cooler conveyor is shown in Fig. 4.

On the hood are located the following items :

(*a*) A door for the passage of the scraper arm
(*b*) The blast-furnace-gas burner
(*c*) The secondary-air connection
(*d*) A door at the bottom, usually left open, through which any lumps coming out of the kiln that are too large to pass through the water-cooled hopper on to the cooler conveyor can be broken up
(*e*) A small auxiliary door used for brickwork repairs.

All the doors have water-cooled frames. Figure 5 is a general view of the kiln, and shows the kiln hood.

Fig. 4—Discharge end of cooler conveyor

The Burner

The gas burner is 19 in. in dia. Inside the burner is a double cone known as the torpedo valve, to which four fins are welded. These fins fit into the forced-air pipe, which is $15\frac{3}{4}$ in. in dia. and fitted in the middle of the burner. Attached to the torpedo valve is a rod with a screwed end protruding through the end of the burner cover. The torpedo valve can be adjusted by a hand wheel on the screw, thus controlling the aperture for forced air. If the torpedo valve is pushed forward there is a larger aperture, which gives a longer flame ; if the valve is pulled back there is a shorter flame.

The gas pressure is controlled by an Askania regulator, normally at 4 in. W.G., the volume of gas burnt being 150,000–280,000 cu. ft./hr., depending on operating conditions. To the right of the burner is the secondary-air pipe, blowing air into the kiln through a 7-in. dia. nozzle. (At present an 8-in. nozzle is being tried.)

There are two air fans, one for primary air and the other for secondary air, the primary air being for gas burning and the secondary air for reoxidization and final combustion. The air for these fans is pre-

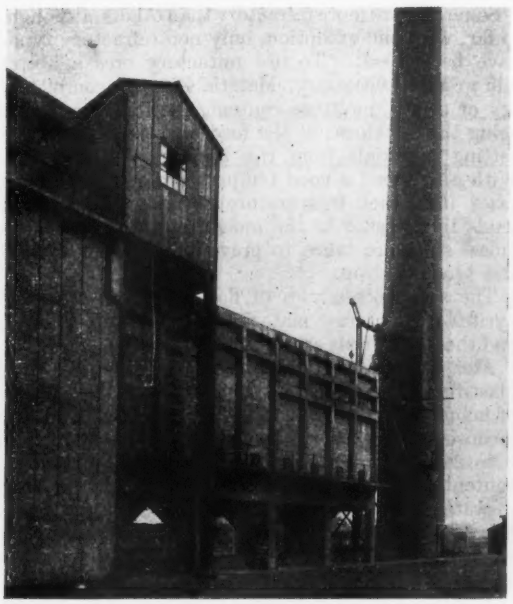


Fig . 3—View of dust chamber, chimney, and long drag chain

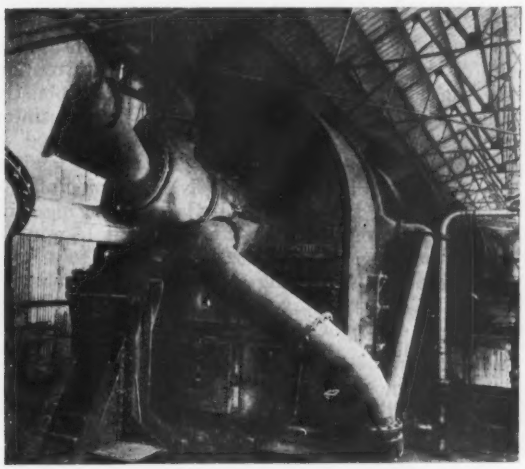


Fig. 5—General view of kiln, showing kiln hood, gas burner, and secondary-air pipe

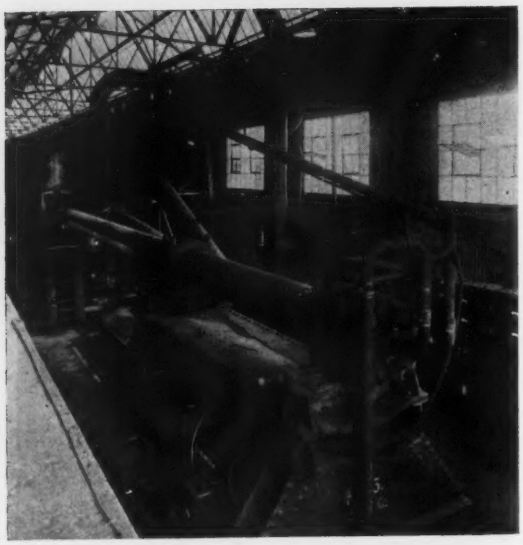


Fig. 6—Scraper car

heated to about 150° C. by the induction through the cooler conveyor. The fans are fed from a common main, but are delivered separately, the volumes of air being 370,000–470,000 cu. ft./hr., primary, and 250,000–300,000 secondary, both at a pressure of 12 in. W.G.

The burner and the secondary-air pipe can be seen in Fig. 5.

Scraper Car

The walls of the sinter zone, where the actual agglomeration takes place, quickly thicken up and must be cleared about every 2 hr. This is effected by a scraper car (*see* Fig. 6). Attached to the car is a hollow forged-steel, water-cooled tube, at the end of which a knife-piece consisting of three sections of riveted steel plate is inserted. The tube is 41 ft. long and $15\frac{3}{4}$ in. outside dia. The tube wall at the front end is $1\frac{3}{16}$ in. thick and 2 in. thick for the last 28 ft., the bore being reduced to suit. The front end of the scraper tube is on a pedestal in front of the kiln hood and the back end is fixed to a robustly constructed car which runs on rails. When the sinter zone requires scraping, the door on the hood is opened and the scraper car pushes the knife against the coating of the kiln as it revolves, scraping off the excess coating. It thus acts like a large boring machine and under normal conditions takes about 15 min. to scrape the kiln.

When the kiln is being scraped a larger quantity of finished material leaves the kiln. To cope with this the cooler conveyor is speeded up.

Kiln Lining

The thickness and type of brick used for lining the kiln vary with each zone :

	Thickness, in.	Brick Type
(1) Barrel	7	*A*
(2) Small zone	7	*B*
(3) Big zone or well	8	*B*
(4) Sinter zone	8	*B*

The characteristics of the brick types *A* and *B* are given below :

	Type *A*	Type *B*
SiO_2, %	65·6	68·0
Al_2O_3, %	25·5	25·0
Fe_2O_3, %	5·3	3·7
Refractoriness under load, ° C. :		
Beginning of subsidence	1200	1200
10% of subsidence	1440	1460
Porosity, %	15·8	20·4
After-contraction (2 hr. at 1400° C.), %	Nil	0·97

To determine the effect on the brick of blast-furnace gas at 450–500° C. a specimen of each type of brick was tested for 400 hr. and failed to disintegrate. The bricks are laid with neat Portland cement.

OPERATING DETAILS

Raw Materials

The kiln can agglomerate all fine materials that are used for blast-furnace purposes. Whilst blast-furnace gas is used as the main fuel, it is necessary to have a minimum of 4% of carbon from flue dust. If there is insufficient carbon, this should be made up with coke breeze, although so far, at Cardiff, this has not been necessary. Kilns have been designed to use entirely fine ore, but the gas and air must be pre-heated to 300° C. and 450° C., respectively, by means of recuperators. As the Cardiff plant was designed to treat a large percentage of flue dust no provision has been made for recuperation.

The particle size is unimportant, provided that the material can be digested in the process, agglomeration being essentially a fusion process. If the ore is very fine and dry there is a tendency for more to be carried over into the dust chamber, although, even so, the amount is relatively small, being only a few crane grabs per shift, and is remixed with the ore.

Some ores are more refractory than others, although, so far, with one exception, only non-refractory types have been used. To use refractory ores a hotter kiln would be necessary. Materials may be completely dry or of any moisture content, the limiting factors being the stickiness of the feed and the difficulty of getting materials from the bunkers into the kiln. With a dry feed a good temperature of the outgoing gases (the back temperature) is maintained, but it tends to decrease as the moisture content increases, unless steps are taken to prevent it, and the output also tends to drop.

The average analyses of flue dust, fine ores, and pyrites used as raw material are given in Table I, and these materials are considered further below.

Flue Dust—Flue dust is obtained from the local blast-furnace plants, and as only a small quantity of home ore is used it is fairly rich in iron. Its main inconsistency is the carbon content, which varies from 8 to 24%, but is normally 12–16%. The moisture content depends on the extent to which the flue dust is watered or pugged at the furnace plant. Stock flue dust which has been in the open for a considerable time always contains moisture and in very wet weather becomes waterlogged and is difficult to handle.

Pyrites—Pyrites residues are very easy to agglomerate. Hence it is always advantageous to have them in the mixture, and fairly large lumps, up to about

1½ in. cube, can be assimilated in the process. The main disadvantage of pyrites is its sulphur content of 2–5%.

Fine Limestone—Because of the shortage of lumps or chippings for blast-furnace consumption, fine limestone has been used through the kiln. This material presents no difficulty, any odd lumps which are too big being found as free lime in the agglomerate. Normally all the fine limestone is assimilated in the finished material and the agglomerate breaks down into small pieces if put into stock for a period.

Fine limestone should not be used when starting the kiln, as it makes a weak, soft coating in the sinter zone, but it can be included as soon as a good coating has been formed. With the improvement in lump limestone supplies, the use of fine limestone has been discontinued.

Starting the Kiln

When starting the kiln, a small wood fire is lit in the sinter zone. The gas valve is then opened, the gas–water seal at the plant is emptied, and the gas coming through the burner ignites. The primary-air fan is now started, the gas thus being burnt with forced air. After ¼ hr. the kiln is rotated slowly and kept turning, with the damper almost closed, so that the heat is distributed properly throughout the kiln and the discharge end is sufficiently warm. When the back temperature is 400° C. half the feed is put on. This takes about 3 hr. to travel down the kiln, fill the well, and come over the step to be agglomerated. If the kiln is not hot enough when the material comes over the step, it is stopped and warmed up. Normally, both the kiln and the material at this point are sufficiently hot.

As soon as the material passes into the sinter zone, the secondary air is started. As it enters the sinter zone, the charge is composed of incandescent dust and small pieces at a temperature of about 1100° C. Here it agglomerates into nodules and clinker, passing out of the kiln in a more or less plastic state and at the same time forming a coating on the wall of the sinter zone. When a thick enough coating has gathered, a scrape is given. As the kiln starts to produce, the damper is gradually opened and the speed of the kiln and the feed are increased to full capacity. The amount of gas, primary and secondary air, the damper position, and the speed of the kiln depend on the temperature and general condition of the kiln, the amount of feed, and the materials being used. The kiln normally operates at approximately full speed, that is, one revolution every 30–35 sec., but if the product goes off quality or is cold, the speed and the feed are reduced. The amount of raw materials used is 22–32 tons/hr., according to the output required and the ability of the kiln to deal with it.

When starting up, a feed containing a higher percentage of flue dust is used, with no refractory ores. As soon as the kiln is producing a good agglomerate, the proportion of flue dust is decreased and that of ore is increased until the normal feed is obtained. Each bunker is set to deliver a definite quantity and, once set, the feed is seldom altered.

However, if the kiln goes cold or is making only very small agglomerate, the proportion of flue dust is again increased. This normally involves taking off 2 tons of fine ore and increasing the flue dust by the same amount.

The carbon content of the feed varies from 4 to 12%. The higher the carbon content the hotter the kiln becomes, but this is offset by using less gas. The maximum percentage of flue dust that has been used on this plant is 80%, and there should be no difficulty in using 100%, as has been done elsewhere.

Table I

AVERAGE ANALYSIS OF RAW MATERIALS

	H_2O	Fe	Mn	SiO_2	Al_2O_3	CaO	MgO	P	S	C
					Flue Dust					
Cardiff (basic)	4·4	39·15	1·21	8·11	3·91	7·7	2·26	0·46	0·43	13·00
Cardiff (hematite)	3·62	44·25	0·66	7·75	2·42	5·90	1·56	0·045	0·32	10·82
Briton Ferry (hematite)	7·50	39·90	0·70	7·37	2·00	2·80	2·10	0·029	0·52	7·20
Margam (basic)	5·20	39·50	0·80	10·20	4·80	4·20	2·00	0·26	0·25	11·00
Ebbw Vale (basic)	3·70	39·50	0·42	12·30	4·40	4·90	1·70	0·87	0·19	12·40
					Fine Ores					
Benisaf	10·7	49·60	1·20	4·60	1·76	0·48	0·59	0·035	0·189	...
Granada	10·80	51·11	1·67	3·43	0·67	2·80	0·92	0·022	0·037	...
Alquife	12·37	48·72	1·20	3·82	1·00	3·50	0·95	0·013	0·016	...
Sierra Menera	14·45	45·91	1·85	5·48	0·81	0·67	1·20	0·063	0·016	...
Bilbao Spathic	0·63	56·48	0·95	7·27	0·78	2·40	4·80	0·014	0·44	...
Ouenza	5·89	49·65	1·68	4·38	0·43	4·80	1·38	0·008	0·045	...
Marampa concentrates	3·34	63·70	0·14	4·20	1·26	0·14	0·58	0·009	0·01	...
					Pyrites					
Irish	4·62	55·27	0·1	2·65	0·77	0·50	0·53	0·022	3·46	...
Widnes	12·20	52·60	Trace	1·80	0·70	0·54	0·25	0·013	3·65	...
Saltney	1·70	59·00	...	4·00	1·50	0·54	0·47	0·014	2·00	...
Ipswich	2·30	58·90	0·07	2·97	1·80	0·56	0·42	0·026	3·40	...
Leeds	11·00	52·40	0·05	5·10	0·80	0·31	0·57	0·011	3·80	...

Table II

A TYPICAL KILN STARTING SCHEDULE

(Date : 10th January, 1950)

Time	Gas Vol., cu. ft./ hr.	Back Temp., ° C.	Comb. Air Temp., ° C.	Position of Damper,* ft.	Wt. of Feed, tons/hr.	Remarks
1.30 a.m.	Kiln lit					
2 a.m.	160,000	150	...	2	...	
3 a.m.	160,000	210	...	1	...	Starting Feed, tons/hr. :
4 a.m.	160,000	240	...	1	...	Flue dust 15
5 a.m.	160,000	260	...	1	...	Alquife 6
6 a.m.	160,000	280	...	1	...	Pyrites 2
7 a.m.	160,000	300	...	1	...	Marampa concentrates 2
8 a.m.	160,000	320	...	1	...	Full feed 25
9 a.m.	250,000	335	...	1	...	
10 a.m.	230,000	365	...	1	...	
11 a.m.	200,000	390	...	1	...	
12 noon	270,000	420	...	1	...	Feed put on kiln at 12.05 p.m., 13 tons/hr.
1 p.m.	260,000	370	...	3	13	
2 p.m.	260,000	375	...	3	13	
3 p.m.	260,000	380	...	3	13	Feed started to come over step into big zone
4 p.m.	260,000	380	50	5	13	
5 p.m.	260,000	400	75	6	18	Agglomerate small
6 p.m.	260,000	370	95	6	23	6.0 p.m. kiln scraped. Agglomerate small
7 p.m.	260,000	370	105	6	23	Good agglomerate made from now on
8 p.m.	260,000	365	125	6	23	
9 p.m.	260,000	360	135	7	23	8.45 p.m. kiln scraped
10 p.m.	260,000	345	135	7	23	Marampa concentrates put on at 10.15 p.m.
11 p.m.	260,000	360	135	7	25	
12 midnight	260,000	360	140	7	25	
1 a.m.	260,000	350	160	7	25	1.05 a.m. kiln scraped
2 a.m.	260,000	400	145	7	25	
3 a.m.	260,000	380	150	8	25	3.10 a.m. kiln scraped
4 a.m.	260,000	370	145	8½	25	
5 a.m.	260,000	370	165	8½	25	5.05 a.m. kiln scraped

* The damper winch is geared down so that 1 ft. on the damper rope represents 0·38 ft. on the actual damper. The readings refer to the position of the damper rope

Sulphur is only partially removed in the process, the maximum being about 50% ; the higher the carbon in the feed the less sulphur is removed. When there is a persistent shortage of gas and the pressure drops, the kiln goes off quality, but if this is expected it is advisable to stop and warm up the kiln.

A typical starting schedule is reproduced in Table II. During the few days following this working the amount of gas burnt per hour was gradually reduced, the flue dust was decreased, and the ore was increased until the feed was made up as follows :

	Tons/hr.	%
Flue dust	9	36
Alquife fines	11	44
Marampa concentrates	3	12
Pyrites	2	8
	25	100

Under these conditions the analyses of the mixture and of the finished agglomerate were :

	Mixture, %	Agglomerate, %
Moisture	8·30	3·80
Carbon	4·80	Nil
Iron	47·20	58·30
Silica	5·00	7·80
Lime	...	5·20
Alumina	...	3·20
Magnesia	...	1·60
Sulphur	0·98	0·62
Phosphorus	0·15	0·22
Manganese	...	1·22
Ferrous oxide	8·40	71·70
Ferric oxide	58·50	3·85
Loss	8·40	Nil

With 72·22% flue dust the feed is made up as follows :

	Tons/hr.	%
Flue dust	19½	72·22
Ouenza fines	4	14·81
Pyrites	2	7·40
Fine limestone	1½	5·55
	27	99·98

Under these conditions the analyses of the mixture and of the finished agglomerate were :

	Mixture, %	Agglomerate, %
Moisture	3·50	1·60
Carbon	9·00	Nil
Iron	43·20	54·60
Silica	7·60	10·50
Lime	...	9·00
Alumina	...	4·00
Magnesia	...	1·70
Sulphur	1·10	0·75
Phosphorus	0·26	0·36
Manganese	...	0·50
Ferrous oxide	...	67·32
Ferric oxide	...	3·35

Sinter-Zone Coating

The coating of the sinter zone is an important feature of the process. It should not be more than 6 in. thick, although this is occasionally exceeded, and it should be easy to scrape when the kiln is working normally. When starting the kiln it is necessary to put on a good coating. If the kiln is not hot enough on starting up, a weak coating results, which is liable to collapse, involving manual work when the lumps are too big to pass through the chute opening

on to the cooler conveyor. The original practice was to dig out the coating with pneumatic drills when the kiln was shut down for repairs, but present practice is to scrape the kiln carefully before stopping, and on starting up a smaller knife-piece is used. There is therefore no need to remove the coating from the sinter zone unless the bricks underneath have worn thin and require renewing.

When a high percentage of flue dust and pyrites is used the kiln tends to become too hot and the agglomerate in the sinter zone becomes sloppy. If this is not checked the coating may be washed away, leaving the brickwork exposed to erosion. Long stoppages for repairs or other causes of heat loss produce 'hard scrapes.'

When stopped for temporary repairs, it is necessary to rotate the kiln about a turn every half-hour. This is to prevent uneven heating, which might cause the barrel to warp.

Adjustment of the Burner

The torpedo valve is set to the position which has been found to give the best results and is very seldom altered, discretion being used when making an alteration. A long flame puts more heat in the big zone and also slightly raises the back temperature, but the danger is that if balls have formed in the big zone they will grow larger and coating may form in the big zone. Too short a flame concentrates the heat too far back in the sinter zone and the material leaves the big zone insufficiently warmed.

The burner should be set to throw the flame on the wall of the sinter zone 9 ft. from the end and 2 ft. from the bottom. The secondary-air nozzle should be set to throw a stream of air 7 ft. from the end of the sinter zone and 2 ft. 4 in. from the bottom. It is most important that the gas burner and the secondary-air nozzle are correctly set.

Control of the Kiln

All the operations are controlled from a central switchboard on the operation platform. The following items are controlled by switches and rheostats :

Tonnage of feed entering the kiln
Belts conveying materials to the kiln
Quantity of primary and secondary air
Cooler conveyor
Rotation and speed of kiln

The following items are continuously indicated or recorded :

Temperature of outgoing gases (the back temperature)
Volume of gas being used
Gas pressure
Speed of kiln

The following items are indicated only :

Pressure of primary and secondary air
Chimney draught
Consumption of the kiln motor (amp.)
Consumption of each motor operating the feeders from the bunkers (amp.)

A klaxon sounds if the kiln inlet becomes choked. The damper is controlled by a hand-winch near the control board.

Output and Performance

The kiln yields 16–20 tons/hr., depending on the amount of feed and its characteristics. The output of the kiln is 3000–3200 tons/week, the record weekly output being 3648 tons.

When the kiln is settled down on a proper feed it will work regularly for days without a stop, after which minor mechanical or electrical repairs may be required. The longest continuous run to date is 21 days. The kiln normally runs for 15–20 weeks and is then taken off for repairs or other reasons. The life of the brickwork and other performance data are as follows :

Sinter zone	6 to 12 months
Big zone	12 to 15 months
Small zone	15 to 24 months
Barrel	2 to 3 years (longer at top end)

Amount of brickwork used = 3–3·5 lb./ton of agglomerate
Power consumption = 7 kW./ton
Blast-furnace-gas consumption = 9000–12,000 cu. ft. per ton of agglomerate, depending on materials used.

Shutting Down

When shutting down, the kiln is scraped, the gas is sealed off, and the feed is stopped. The damper is then almost closed, the kiln being kept turning the whole time. The damper is kept closed in order to concentrate the heat in the sinter zone. If the damper were open to any extent, heat would travel into the big zone and coating would be formed as the feed decreased. In a short time the kiln cools down and the feed turns into dust, which can be reprocessed. After the gas is sealed off, the kiln is given one or two scrapes before becoming too cold.

When the material is too cold to agglomerate, the damper is opened so as to draw cold air in to help cool the kiln, which can be stopped revolving when the back temperature drops to 120° C. In about 12–16 hr. it is cold enough to enter.

Hazards in Kiln Operation

Rings—Rings, which normally form in the big zone, occur when the material sticks to the wall beyond the reach of the scraper car, and they usually occur without warning. Thickening is observed on the wall of the big zone and it gradually increases until a ring is formed inside, which, if allowed to grow, would seal up the whole of the big zone. It usually grows so rapidly that after about 8 hr. the effective diameter of the big zone is reduced to the diameter of the sinter zone and the outlet for the gases is very restricted. The inside perimeter of the ring becomes still hotter, so that the ring grows even more rapidly. Once a ring has formed little can be done, although sometimes it will remain the same size for a period of several days and ultimately disappear. This is a rare occurrence, however, and there is always the danger of it getting larger.

When a ring begins to form the first step is to cool the kiln by reducing the gas and air and by adding more ore to the feed. This results in insufficient heat to agglomerate the material; only dust is produced, which has to be reprocessed. By this means the ring contracts and if it cracks it may collapse. This method is seldom effective, but it is the only way of

tackling a ring during operation. The method causes a lot of dust and mess due to the fact that only hot dust, which blows about, comes out of the kiln. When a ring is firmly established it is always better to shut down the kiln and, when it is cold enough, to go inside and cut it out with pneumatic picks. Prolonged efforts to bring it down frequently cause it to grow, involving a lot of unnecessary hard work and a much longer shut-down.

Rings are caused by shortage of feed, a too high temperature in the kiln and, above all, incorrect setting of the gas burner and the secondary pipe. If these are not adjusted correctly, the flame is concentrated in the big zone.

With good kiln operation rings should cause no trouble. At the author's plant no rings have occurred during the last six years, although they caused trouble when the plant first started.

Balls—The balls that form in the kiln are often not quite round, but are simply lumps; they are less troublesome than rings. One cause is shortage of feed, and they tend to form when too long a flame is used, that is, when the torpedo valve is in too far. Sometimes they form for no apparent reason.

When the kiln started up originally, with an abnormally high back temperature, a large ball was formed and in the course of a few days became so large that it was necessary to shut down the kiln and break up the ball with pneumatic picks. This has not occurred again.

Sometimes a ball will reach a certain size and remain in the zone at that size for the whole campaign, or it may continue to grow. On the other hand, if the kiln is allowed to cool the ball may travel up the kiln and break into several pieces, which will come down again into the big zone.

When there are two or more balls in the big zone they usually wear away or break themselves up, or one might knock the other out. A large and very round ball may roll down the sinter zone and damage the hood.

Small balls and lumps often come out of the big zone. They do not cause any trouble unless they are too large to go down the chute and have to be broken up by hand. Actually, the formation of balls now causes little trouble and it is seldom that the kiln has to be stopped. If a ball comes over, the operator pulls it through the hood opening and breaks it up with a sledge hammer, but if it is too big to come out of the hood opening the gang break it up with a bar and tup.

AGGLOMERATE AS A BURDEN CONSTITUENT

Physical Properties

Agglomerate and sinter have different characteristics and it is the experience at Cardiff that 25% of the former in the furnace burden retards driving, whilst at a higher percentage the furnace works very stiffly. It is therefore the practice not to use more than 25%. This does not necessarily apply at other works, where experience indicates that 25% is not the maximum amount that can be used. On account of a high FeO content, the material is not very reducible, and as the finishing temperature of the kiln is 1100–1200° C. it is also semi-plastic when this temperature is reached.

The amount of FeO and Fe_2O_3 varies in the agglomerate, and efforts have been made, without success, to increase the Fe_2O_3 content. Because of the carbon in the feed the process is basically a reducing one, and one of the functions of the secondary air in the sinter zone is ostensibly to reoxidize some of the FeO to Fe_2O_3 before discharge on to the cooler conveyor.

The average analysis of the product over the last few months is 62·91% of FeO and 12·70% of Fe_2O_3.

Size of Material

The present system of loading the finished agglomerate by grab with a steam crane is not ideal. It is necessary to cool it after it leaves the conveyor by spraying with water, which collects at the bottom of the pit and causes excessive breakage. Originally there was an elevator to take the finished material from the cooler conveyor to a service bunker and thence into wagons, but it was not sufficiently robust and the pit and steam crane are being used until a more satisfactory method can be devised. The finished agglomerate is of fairly consistent size, the following being an average of some sizing tests carried out recently :

		%
Over	1 in.	28·36
	¾ in.	9·25
	½ in.	8·43
	¼ in.	24·12
	⅛ in.	12·70
	1/16 in.	12·54
Under	1/16 in.	4·60

Excessive breaking is shown by the fact that sizing tests taken on the material as it leaves the cooler conveyor gave it a figure of 73% over 1 in.

Comparison with Sinter Plants

The rotary kiln has several advantages over a a sinter plant : 100% flue dust can be used, no coke breeze is required, a bigger variation in the particle size of materials is permissible, eliminating fine crushers, and there are no returns as in sintering. One disadvantage is that the material is not as reducible as sinter. Another is that the kiln must be worked continuously and cannot be operated on a basis of one or two shifts per day. Whilst relatively few rotary kilns for the treatment of fine ore and flue dust are in use, in Luxembourg rotary kilns have been built in preference to sinter plants.

Acknowledgments

The author wishes to thank the management of Messrs. Guest Keen and Baldwins Iron and Steel Co., Ltd., East Moors Works, Cardiff, for permission to publish this paper; also Mr. N. Gray, Chief Metallurgist, for his assistance, and Mr. T. Davies for preparing the drawings.

A Theory of Basicity and Oxidation Applicable to Steelmaking

By W. L. Kerlie, B.Sc., F.I.M.

SYNOPSIS

A re-examination of some of the literature on the subject has been carried out, particular attention being given to the influence of slag basicity on the distribution of FeO between slag and metal. As a consequence a theory of oxidation and basicity has been developed by which the equilibrium oxygen content of the liquid iron can be calculated with reasonable accuracy, given the total iron content of the slag, the temperature, and the basicity. On the molecular theory of slag/metal equilibria it appears necessary to assume the presence of relatively inactive $(FeO)_4$ molecules, the stability of which increases with increasing basicity.

There is a range of slag basicity within which the slag behaves more or less as an ideal solution, the activity of the FeO being essentially directly proportional to the mol fraction. At lower values of basicity there is a positive deviation and at higher basicities a negative deviation from Raoult's law. These deviations indicate that with neutral slags there is a high degree of dissociation of the $(FeO)_4$ molecules. A similar effect with acid slags is also apparent.

Using calculated values of oxygen content the equilibrium constants for the phosphorus and manganese reactions have been evaluated and compared with the constants based on analytical oxygen contents.

The distribution of sulphur between metal and slag indicates that the FeO in the slag has two different actions, depending on its concentration and the basicity of the slag, and suggests the presence of dissociable $(FeO)_4$ molecules.

A special series of experiments on a production scale in a basic Bessemer converter has shown that the oxygen content of the steel is an important factor influencing the final nitrogen content. The importance of other factors is revealed by a simple method of examining mass data.

The examination of experimental data on open-hearth heats reveals the possibility of an improvement in the refining technique.

Most of the important contributions to the thermochemistry of steelmaking have been made during the last 25 years, and reasonably accurate methods of slag control have been developed recently and put into practice with encouraging results. That the basicity of the slag has a bearing on the degree of oxidation of the metal has been known in a practical way for many years, and several attempts have been made in the past to correlate basicity and oxidation in precise mathematical terms and in a manner suitable for everyday practical use. A certain measure of success has been achieved, but some uncertainty always existed because of the empirical nature of the results and the tedious work involved in their application. Rapid progress has been made in recent years in the laboratory and, in terms of steelmaking slags, the latest definition of a base given by Chipman[1] is as follows :

> "A base is a donor of electrons, an acid an acceptor. In oxide slags the typical and ever-present base is oxide ion, O^{--}."

and the acceptance of this definition is necessary in the ionic theory of slag/metal equilibria.

Equally necessary in terms of practical steelmaking is the development of the idea of basicity expressed as $(CaO)/(SiO_2 + P_2O_5)$ and referred to as the V ratio. The following work was carried out with the idea of developing this expression so that more precise information would be obtained on the factors influencing the basicity of the slag and the effect of basicity on the degree of oxidation of the metal, bearing in mind the development of a simple theory of slag/metal reactions suitable for immediate application to steelmaking practice.

GENERAL THEORY OF BASICITY AND OXIDATION

Oxygen Content and Temperature

Taylor and Chipman[2] have determined the saturation value for oxygen dissolved in liquid iron and have expressed the variation with temperature thus :

$$\text{Log } [O]\% = -\frac{6320}{T} + 2{\cdot}734 \quad \text{.....(1)}$$

As the first step in an attempt to understand the influence of basicity the data of Fetters and Chipman[3] were examined, the oxygen contents of the iron being corrected to values at 1600° C. using Taylor and Chipman's expression, which is illustrated in the form of a graph in Fig. 1. The saturation value at a temperature t° C. (S_t) is found from the graph and the oxygen content at 1600° C. is given by :

$$[O]_{1600} = \frac{[O]_t \times S_{1600}}{S_t} = \frac{0{\cdot}229\,[O]_t}{S_t} \quad \text{.....(2)}$$

the saturation value at 1600° C. being 0·229.

To obtain more values at lower concentrations of (FeO) in the slag the data of Winkler and Chipman[4] were also examined. A plot of $[O]_{1600}$ against total iron oxide in the slag (ΣFeO) was then drawn (as shown in Fig. 4), the value (ΣFeO) representing the total iron content of the slag expressed as FeO. A straight line through the points, from the origin to the saturation value, corresponds closely to the partition coefficient L_{FeO} proposed by Körber and Oelsen,[5] the value in this case being 0·0103.

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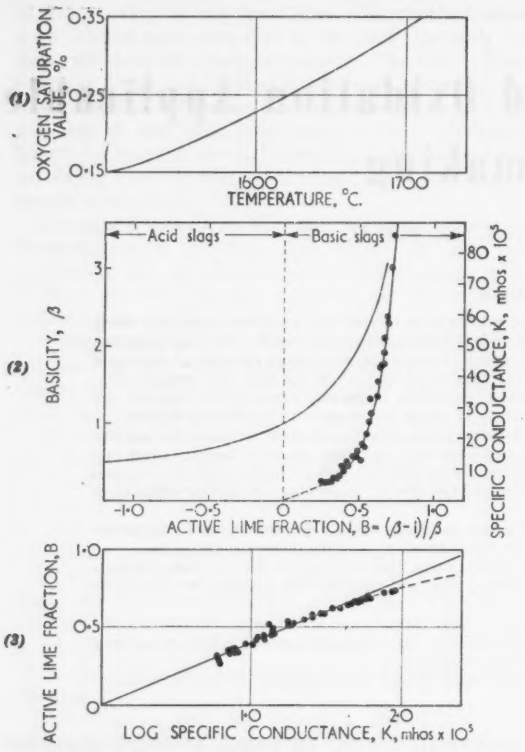

Fig. 1—Variation in the saturation value of oxygen dissolved in liquid iron, according to Taylor and Chipman

Fig. 2—Variation in the specific conductance of water extracts and the β value with the active lime fraction, based on the data of Smith, Monaghan, and Hay

Fig. 3—Correlation between log specific conductance and the active lime fraction

Measure of Basicity

On drawing lines through the maximum and minimum oxygen values in Fig. 4, it was realized that the former corresponded to slags within the range of V ratio, $(\%CaO)/(\%SiO_2 + \%P_2O_5)$, 1·0–1·4, whilst the minimum oxygen values corresponded to the very acid or very basic slags with low or high V ratios. The V ratio was chosen initially as the measure of basicity because, as has been found from experience and as shown by Fairley,[6] this value has given very satisfactory results in actual steelmaking practice.

After grouping all the slags according to V ratio it was found that the correlation between $[O]_{1600}$ and (ΣFeO) could be represented by a series of curves which progressively flattened out towards the L_{FeO} diagonal with V ratio increasing or decreasing from unity. That is, for any given iron content in the slag, the oxygen content of the metal was a maximum when the V ratio approached unity. Within each group of slags, however, there was a considerable degree of scatter, and slags having a high P_2O_5 content lay above the average line through the points and those with a high MnO content were below the line. MgO did not appear to have any influence one way or the other and it was assumed, as for FeO, that this compound was essentially neutral. It should be noted that, in terms of relative bond strength,[7] MgO is more similar to FeO than to CaO.

In making the basicity corrections a systematic scheme was adopted in which the acids and bases could be considered in terms of lime equivalent, MnO being regarded as having half the basicity of CaO. This led to the expression :

$$\beta = \frac{CaO\% + 0{\cdot}394\ MnO\%}{0{\cdot}933\ SiO_2\% + 1{\cdot}184\ P_2O_5\%} \quad \ldots\ldots\ldots(3)$$

which is the ratio of the total lime equivalent to the lime required for compound formation, assuming the compounds $CaO.SiO_2$ and $3CaO.P_2O_5$. In the case of alumina the factor was taken as 0·916, based on $5CaO.3Al_2O_3$. Körber and Oelsen[8] have shown that fluorspar increases the activity of FeO in the slag and this effect was confirmed in the present examination, the oxygen content in the case of slags containing CaF_2 lying above the average line. The factor for CaF_2 was taken as 0·359, based on the assumption that fluorspar had only half the acidity of silica, but the issue is, no doubt, further complicated by the fact that stable fluorapatite is formed in phosphate slags.

Smith, Monaghan, and Hay[9] have shown that the V ratio of a basic open-hearth slag can be represented as a function of the conductance of a water extract, no doubt because of the dissociation of the lime compounds present in the slag and subsequent hydrolysis of the free CaO. The slags examined covered a V ratio range of 1·4–3·5 and, as was shown in the discussion of their paper,[10] an equally good correlation could be found if the V ratio were expressed in the molar form :

$$V_{mol} = \frac{CaO}{0{\cdot}933\ SiO_2 + 1{\cdot}184\ P_2O_5} \quad \ldots\ldots\ldots(4)$$

This expression corresponds to the β value given above, the values of (MnO) being fairly constant.

Significance of the β Value

The fundamental significance of the β value may be explained as follows :

$$\beta = \frac{CaO\%}{0{\cdot}933\ SiO_2\% + 1{\cdot}184\ P_2O_5\%} \quad \ldots\ldots\ldots(5)$$

$$\therefore \frac{\beta - 1}{\beta} = \frac{CaO\% - 0{\cdot}933\ SiO_2\% - 1{\cdot}184\ P_2O_5\%}{CaO\%}$$

$$= \frac{(CaO')\%}{(\Sigma CaO)\%} \quad \ldots\ldots\ldots(6)$$

which is the ratio active-lime/total-lime, or the active lime fraction, the term (CaO′) being essentially the same as the basicity expression of Schwarz.[11] Dividing both numerator and denominator by 56, the molecular weight of CaO, and by N, the total number of mols, does not alter the value of the expression and gives the molar fraction of active lime per unit molar fraction of total lime, *viz.*:

$$B = \frac{\beta - 1}{\beta} = \frac{\frac{(CaO')\%}{56N}}{\frac{(\Sigma CaO)\%}{56N}} = \frac{x_{(CaO')}}{x_{(\Sigma CaO)}} \quad \ldots\ldots\ldots(7)$$

Since the activity of pure CaO may be regarded as unity, the active lime fraction $(\beta-1)/\beta$ is a measure of the activity of the CaO present in the slag, or the basicity. It is not, however, the 'true' or thermodynamic activity, except, perhaps, at very high concentrations of lime, since the total lime exists as

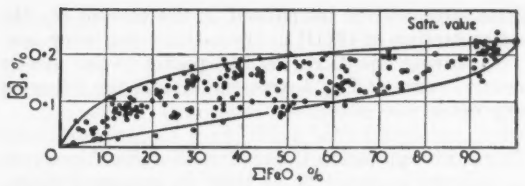

Fig. 4—Variation in oxygen content with total FeO in the slag, based on data of Fetters and Chipman, and Winkler and Chipman

several different types of compound unless it be regarded as completely ionized in liquid slags.

The V ratio for each of the various compounds is approximately the same as the β value and with most basic open-hearth slags in which silicates and phosphates are both present, V and β are essentially identical. It is also interesting to note that for acid slags $(\beta-1)/\beta$ is negative, for neutral slags $(\beta-1)/\beta = 0$, and for basic slags the values are all positive. Denoting the active lime fraction $(\beta-1)/\beta$ by B:

$$\beta = \frac{1}{1-B} = 1 + B + B^2 + B^3, \text{ etc.} \quad \ldots\ldots (8)$$

and the maximum value for β is infinity, which is the value for pure lime.

In Fig. 2 is shown the variation in specific conductance and β value with active lime fraction, based upon the data of Smith, Monaghan, and Hay. The correlation between the specific conductance κ and the active lime fraction B is particularly good, and on

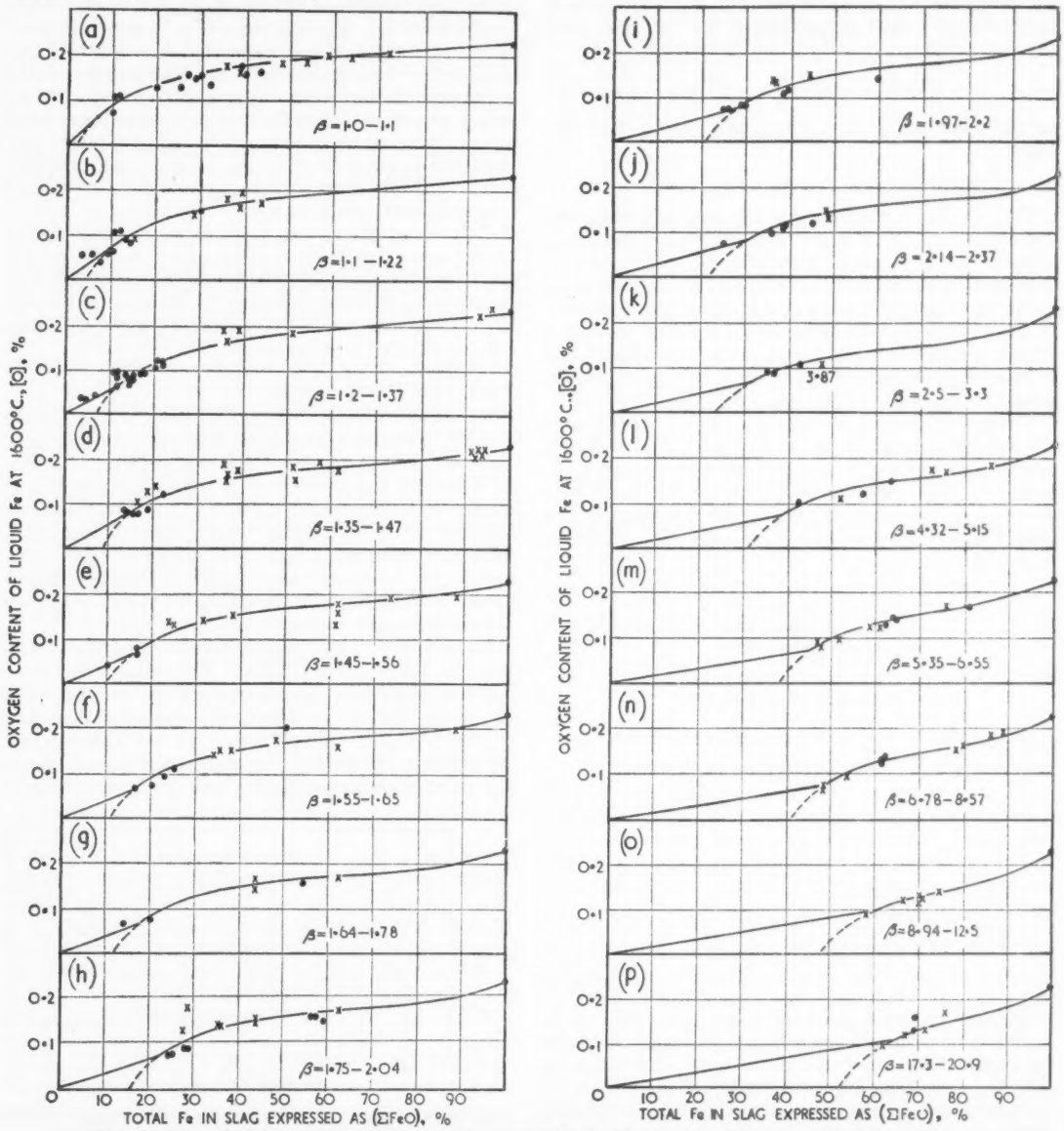

Fig. 5—Variation in oxygen content with total FeO in the slag for different basicity ranges

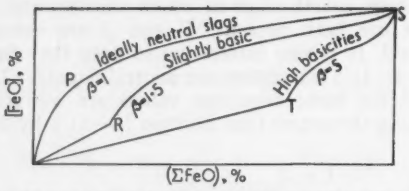

Fig. 6—Change in oxidation as the result of change in basicity, illustrated diagrammatically

plotting B against log κ, as shown in Fig. 3, the following straight-line equation was obtained:

$$B = 0{\cdot}4 \log \kappa \quad \text{.....(9)}$$

This equation clearly indicates that B is a measure of the activity of the CaO present in the slag, and gives the expression:

$$\beta = \frac{1}{1 - 0{\cdot}4 \log \kappa} \quad \text{.....(10)}$$

for determining β from the conductance of water extracts.

Mechanism of Oxidation by the Slag

The β values for the slags in the data of Fetters and Chipman and of Winkler and Chipman were calculated and separated into groups to give, as far as possible, a wide range of (ΣFeO) content and a narrow range of basicity for each group. Thus, the variation in the oxygen content of the liquid Fe with increasing (ΣFeO) in the slag was plotted as shown in Fig. 5, and it became immediately apparent that a good correlation was obtained in each case.

The upper line in Fig. 4 (*see* also Fig. 6), representing the ideally neutral slags, conformed fairly well to a fourth-root law and it was decided to investigate the nature of the reaction involved on the basis that associated molecules of $(FeO)_4$ were present in the slag along with simple (FeO) molecules. The argument was as follows:

C_1 = concentration of [FeO]; C_2 = concentration of (ΣFeO)
L = partition coefficient of (FeO) between metal and slag
α = fraction of (FeO) molecules; $(1 - \alpha)$ = fraction of $(FeO)_4$ molecules
D = dissociation constant of the reaction $(FeO)_4 \rightleftharpoons 4(FeO)$

Therefore αC_2 = concentration of (FeO)

$\frac{(1 - \alpha)C_2}{4}$ = concentration of $(FeO)_4$

$$L = \frac{C_1}{\alpha C_2} \text{ or } \alpha C_2 = \frac{C_1}{L} \quad \text{.....(11)}$$

$$D = \frac{4\alpha^4 C_2^4}{(1 - \alpha)C_2} \quad \text{.....(12)}$$

From equation (12):

$$4\alpha^4 C_2^4 + D\alpha C_2 - DC_2 = 0 \quad \text{.....(13)}$$

From equations (11) and (13):

$$4\frac{(C_1)^4}{(L)} + D\frac{(C_1)}{(L)} - DC_2 = 0 \quad \text{.....(14)}$$

Strictly speaking, since the reaction depends on the collision of molecules, equation (14) applies to molar concentrations, and D is only a 'true' constant if the (FeO) in the slag behaves ideally. Consequently, a certain degree of error is to be expected if concentrations are expressed on a weight-percent basis, but little error will be introduced in the case of C_1, the concentration of [FeO] in the metal being very low.

In solving equation (14) two points on the ideally neutral curve of Fig. 4 were chosen and the following expression was obtained:

$$66{\cdot}3\,C_1^4 + 12{\cdot}7\,C_1 = C_2 \quad \text{.....(15)}$$

From this expression the saturation value for oxygen in solution in liquid Fe at 1600° C. became 0·237%.

To test if the nature of the correlation for each basicity group was the same, or essentially so, a celluloid template was cut to conform to equation (15). Using this template in the same horizontal position an average line was drawn through the points in each group (Fig. 5). It was necessary, without turning the template, to move it downwards and to the right with increasing values of β, but, with values greater than 2, it was only necessary to move the template to the right. It is obvious that a well-fitting line has been obtained in each case. The nature of the correlation is the same throughout, except for an initial period at lower (ΣFeO) concentrations, when the oxygen content of the melt is almost directly proportional to the total FeO in the slag, and except at higher (ΣFeO) concentrations when the curve must rise to the saturation value.

This result shows that with the molecular theory of slag/metal reactions it is necessary to assume the presence of dissociable $(FeO)_4$ molecules. Further confirmation of this was obtained by the fact that working on the basis of $(FeO)_2$ or $(FeO)_3$ molecules gave comparatively poor correlations.

Theoretical Interpretation

Since the gradient of the initial straight-line portion of each curve decreases with increasing basicity and since the length increases simultaneously, it is considered that the presence of $2CaO.SiO_2$, or of lime in excess of that required to form $CaO.SiO_2$, prevents the formation of highly active (FeO) molecules. Although compound formation between CaO, FeO, and Fe_2O_3 no doubt plays a part, it is not sufficient to account for the effect mentioned; the (Fe_2O_3) content of the slags in these zones is too low.

Referring to Fig. 6, lines representing the variation in [FeO] with (ΣFeO) for slags with three different basicities are shown. With neutral slags ($\beta = 1$) $CaO.SiO_2$, $MnO.SiO_2$, $3CaO.P_2O_5$, and $5CaO.3Al_2O_3$ probably exist. At low (ΣFeO) concentrations the FeO in the slag is almost entirely in the form of simple molecules and the oxygen content

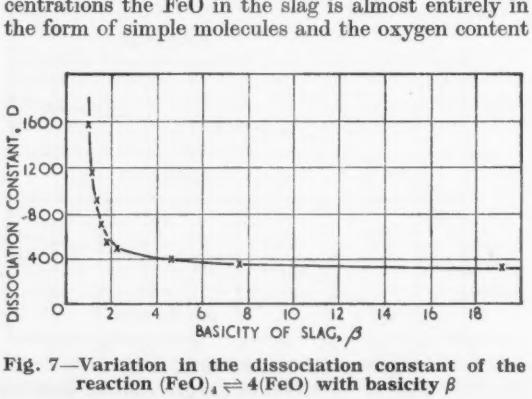

Fig. 7—Variation in the dissociation constant of the reaction $(FeO)_4 \rightleftharpoons 4(FeO)$ with basicity β

of the melt rises rapidly along OP; but with increasing concentration the fraction of (FeO) molecules decreases, with the effect that the curve progressively flattens out towards the saturation value S.

The fraction of simple (FeO) molecules and the dissociation constant D are found from equation (13) by dividing throughout by D and comparing with equation (15), *viz.*:

$$\frac{4}{DL^4}(C_1)^4 + \frac{1}{L}(C_1) = C_2$$

$$66{\cdot}3\,(C_1)^4 + 12{\cdot}7(C_1) = C_2$$

$$\therefore \frac{1}{L} = 12{\cdot}7 \text{ and } \frac{4}{DL^4} = 66{\cdot}3$$

$$\text{Since } \alpha = \frac{C_1}{LC_2}$$

$$\therefore \alpha = \frac{12{\cdot}7C_1}{C_2} \text{ and } D = 1570$$

With slags which are slightly basic ($\beta = 1{\cdot}5$) some $2CaO.SiO_2$ exists, and probably some $CaO.Fe_2O_3$ or $CaO.Fe_3O_4$ results from the reactions :

$$(FeO)_4 + 2CaO.SiO_2 \rightleftharpoons CaO.Fe_2O_3 + FeO + Fe + CaO.SiO_2$$
$$(FeO)_4 + 2CaO.SiO_2 \rightleftharpoons CaO.Fe_3O_4 + Fe + CaO.SiO_2$$

The formation of Fe_3O_4 according to the reaction

$$(FeO)_4 \rightleftharpoons Fe + Fe_3O_4$$

is considered to take place in some measure, but this reaction is not likely to affect the results given above.

Referring again to Fig. 6 it is suggested that when the basicity increases to $\beta = 1{\cdot}5$, the available lime virtually prevents the dissociation of $(FeO)_4$ molecules until a certain concentration R is reached, above which the $(FeO)_4$ molecules dissociate readily into active (FeO) molecules and rapidly increase the oxygen content of the steel.

At high basicities (*e.g.*, $\beta = 5{\cdot}0$) the concentration of simple FeO molecules increases linearly along OT, the fraction being constant, and rapid dissociation of $(FeO)_4$ molecules takes place only at very high (ΣFeO) concentrations.

From the curves in Fig. 5 and from equations (11) and (12):

$$L = \frac{C_1}{\alpha C_2} = 0{\cdot}0786 \text{ and } D = \frac{4(\alpha C_2)^4}{(1-\alpha)C_2}$$

the variation in the dissociation constant D with basicity β has been evaluated as shown in Fig. 7. This curve shows that the concentration of dicalcium silicate is the major factor responsible for the stabilization of $(FeO)_4$, since D drops remarkably with values of β increasing to 2, after which it remains relatively constant.

It is interesting to note that with values of β greater than 2 it becomes increasingly difficult to determine the basicity of open-hearth slags by visual examination of slag pancakes. It is suggested that the appearance of the slag pancake is largely determined by the concentration of dicalcium silicate.

The use of weight-percent concentrations in the foregoing calculations no doubt introduces a certain amount of error, and it was decided to attempt a correlation between the activity of the (FeO) and its mol fraction. Various slags were selected from different basicity groups, and using the same symbols as White[12] and assuming the species CS′, C_3P, C_2S, CMS, CM′S, CS, CF, C_2F, M'_2F, M_2F, F′F, M, M′, and F′, the molar concentrations and the mol fraction of F′ were calculated.

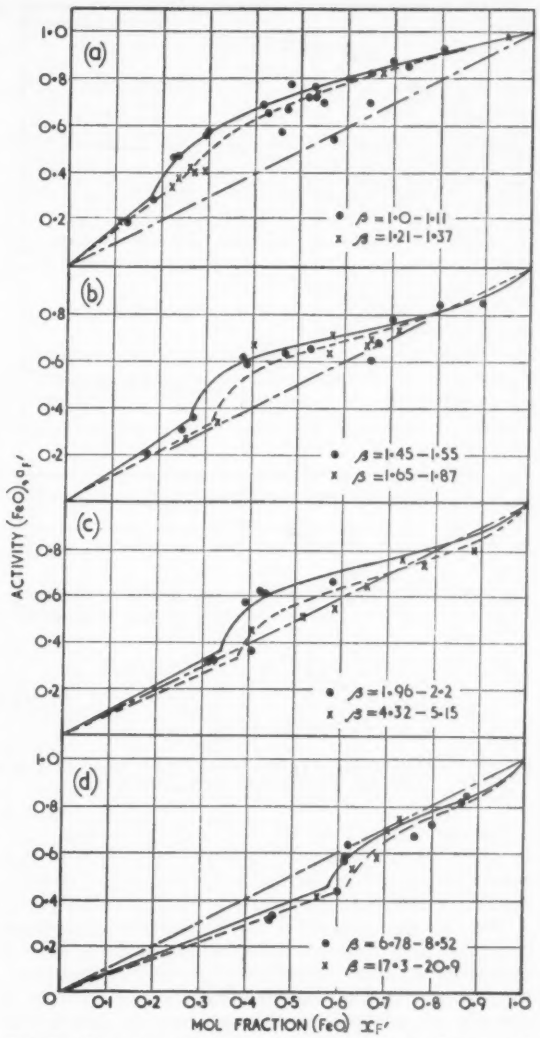

Fig. 8—Plot of activity $a_{F'}$ against mol fraction $x_{F'}$ of (FeO) for eight basicity groups

The activity of F′ was taken as [O]/0·229, where [O] is the oxygen content of the steel and 0·229 is the saturation value, both at 1600° C. and expressed on a weight-percent basis. In this case, because of the low concentrations of oxygen in the steel, the use of mol fractions will not impair the accuracy to any appreciable extent and the small corrections for the entropy and heat of mixing, suggested by Fast,[13] may be neglected in view of the uncertainty in the selection of the compounds in the slag. The mol fraction of (FeO) in the calculation refers to FeO as such by chemical analysis and is the residual (FeO) after allowing for the formation of $FeO.Fe_2O_3$, *i.e.*, F′F. The plot of activity $a_{F'}$ against mol fraction of (FeO) or $x_{F'}$, is shown in Fig. 8 for eight basicity groups.

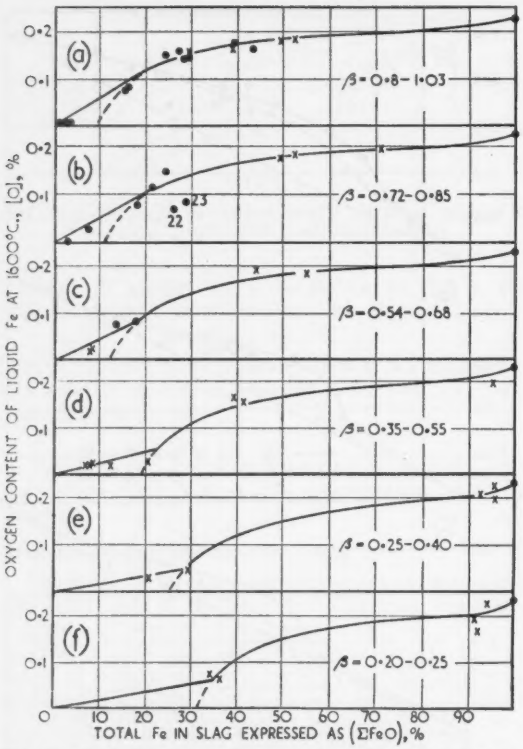

Fig. 9—Variation in oxygen content with total FeO in the slag for the acid slag groups

For pure liquid FeO, $x_F' = 1$, and the activity a_F' is unity. Raoult's law will therefore be obeyed in the case of slags lying on the diagonal, assuming, of course, that the mol species selected are essentially correct.

The two slag groups in Fig. 8*a* indicate a positive deviation from Raoult's law and suggest the presence of associated molecules of $(FeO)_4$. At low mol fractions there is a positive deviation and the activity is directly proportional to the mol fraction, indicating stability of the $(FeO)_4$ molecules, which, if allowed for in calculating the mol fraction, would bring the points nearer the ideal solution line.

The groups in Fig. 8*b* show a smaller deviation with increasing basicity, and from Fig. 8*c* it would appear that slags having β values between 2 and 5 approach ideal behaviour. It is interesting to note (*see* also Figs. 5*i–k*) that in basic steelmaking practice nearly all finishing slags lie within this range of basicity, and Fig. 8*b* (*see* also Figs. 5*d–f*) might be said to represent melt-out slags, in which case the oxygen content of the steel should be directly proportional to the total Fe in the slag. The difficulty at melt-out, however, is that both metal and slag are often non-homogeneous.

Figure 8*d* illustrates a negative deviation from Raoult's law for values of β exceeding 5 and clearly suggests that the activity of the (FeO) remains at relatively low values until the mol fraction exceeds 0·6, at which point there is an appreciable dissociation of $(FeO)_4$ molecules.

Acid Slags

The acid slags are taken to cover the range of β values 0–1. These are plotted in groups in Fig. 9 and show characteristics very similar to the basic slags in so far as the variation in the oxygen content of the metal with (ΣFeO) in the slag is concerned. Compound formation (no doubt $2FeO.SiO_2$ is the stable compound formed) again results in a depression of the curve and at the lower concentrations of (ΣFeO) a straight-line correlation is suggested.

The general nature of the curves again suggests the dissociation of $(FeO)_4$ molecules into simple (FeO) molecules, but the data are insufficient to give further information with the necessary degree of reliability.

Ionic Hypothesis

It should be possible to make use of the above results in developing the ionic theory of slag/metal equilibria. It has been pointed out that the fraction of dissociated simple (FeO) molecules decreases with increasing concentration of (ΣFeO) and that with very dilute solutions the dissociation is practically complete. This is in keeping with the theory of solutions, and dissociation might well be interpreted either as ionization or as a change from complex to simple ions. Chipman and Chang[1] postulate the existence of the two ions O^{--} and $Fe_2O_5^{4-}$, and if the presence of relatively inactive $Fe_2O_4^{4-}$ ions is not possible, then it must almost be assumed that non-ionized $(FeO)_4$ molecules exist.

APPLICATIONS OF THEORY OF BASICITY AND OXIDATION

Calculation of the Oxygen Content

Using Fig. 5 and equation (15), the chart in Fig. 10 was constructed. This represents the variation in the oxygen content of the steel at 1600° C. with the total FeO in the slag for the range of basicities covered in normal basic steelmaking practice. Strictly speaking, this chart applies only to equilibrium conditions in liquid Fe melts, but it should provide close approximations in the case of heats with low carbon contents and approaching equilibrium. With high carbon contents (ΣFeO) is generally very low and, although the data are insufficient to cover this region with the necessary degree of certainty, it should be possible to obtain results which are approximate.

It is considered that Fig. 10 is particularly useful in the case of basic Bessemer melts. In this case the β values usually lie within the range 1·7 to 2·0 and (ΣFeO) generally varies between 13 and 27%, according to the final phosphorus content and temperature. The carbon content at the beginning of the afterblow is in the region of 0·05% and during the early part of the afterblow it drops slowly to 0·03% approximately. At the same time the phosphorus removal is vigorous and for a brief period actually reduces the FeO in the slag to low values. During the remainder of the afterblow the FeO in the slag increases rapidly and, finally, when the phosphorus has reached a low value (0·03%) the carbon content is in the region of 0·01–0·02% and the reaction is essentially one of FeO formation and a continuous adjustment of FeO between metal

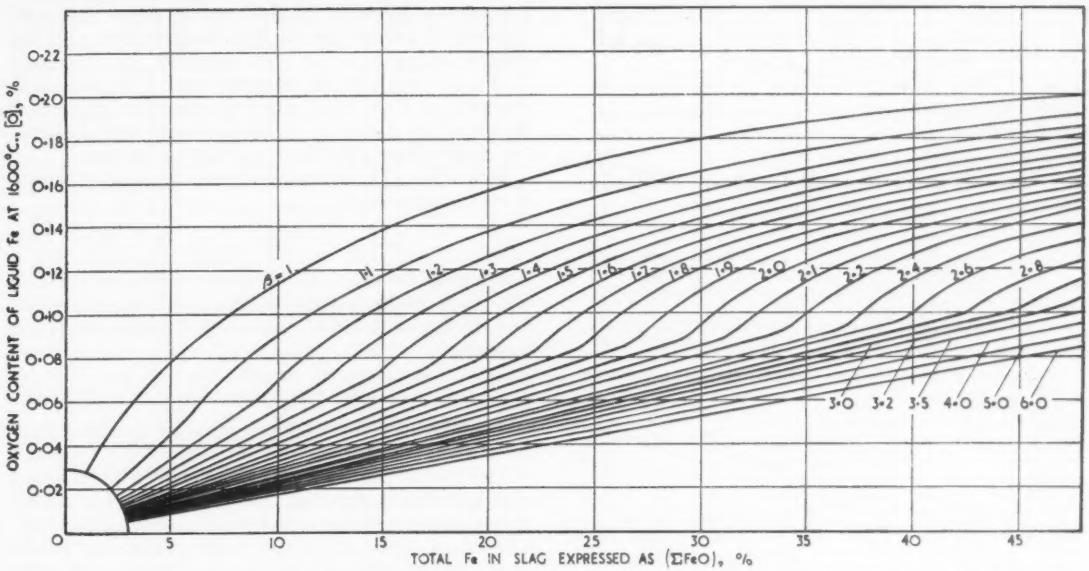

Fig. 10—Variation in the oxygen content of liquid iron at equilibrium and a temperature of 1600° C. for slags of varying basicity and varying total iron oxide content

and slag, which are in very intimate contact. This is evidenced to a certain extent by the values of the [C] [O] product, which are generally about 0·0012, compared with equilibrium values of 0·0024. A similar effect should be observed in the case of the open hearth after refining to a low carbon and increasing the basicity appreciably at the end of refining, but normally the [C] [O] product is in the region of 0·0032.

In calculating the basicity of basic Bessemer slags the Al_2O_3 is low and may be neglected; the MnO does not vary to any great extent, and equation (3) may be used.

Having obtained the total iron oxide (ΣFeO) in the slag (say = 20%), a line is run vertically to meet the β line (say, 1·54), and the horizontal from this point to the oxygen axis gives the oxygen content of the steel (0·09%) at 1600° C. To correct to the steelmaking temperature (say, 1625° C.) the following expression is used:

$$[O]_{1625} = \frac{[O]_{1600} \times S_{1625}}{0{\cdot}229} = \frac{[O]_{1600} \times 0{\cdot}254}{0{\cdot}229}$$

where S_{1625} is the saturation value at 1625° C. obtained from Fig. 1 and found to be 0·254%. The saturation value at 1600° C. is 0·229%.

The Phosphorus Reaction

There are three outstanding papers dealing with the phosphorus reaction:

$$2P + 5FeO + 3CaO = 3CaO.P_2O_5 + 5Fe$$

by Schenck,[14] Winkler and Chipman,[4] and Vajragupta, Quarrell, and Balajiva.[15–17]

Schenck's formula covers a wide range of conditions and, although it can be used with a fair degree of accuracy in practice, it has two demerits: it is awkward to handle and it is based on rather doubtful expressions for the free (CaO) and free (FeO) concentrations. The expression of Winkler and Chipman appears to be more correct fundamentally, but is too elaborate to be of real practical value. Vajragupta's formula, which is quite empirical, has the great advantage of simple practical application, but covers only a small range of basicity.

Character of the Phosphorus Equilibrium Constant

In the following work Vajragupta's data were used, the oxygen content of the melt being calculated by the method outlined above. The data of Winkler and Chipman were used for comparison, since in this case the oxygen content of the melt had been determined by analysis.

In the first instance the reaction was assumed to be of the form:

$$2[P] + 5[O] + 3(CaO) \rightleftharpoons (3CaO.P_2O_5)$$

and the basicity term chosen was:

$$\frac{(CaO + 0{\cdot}394\ MnO)\ (\beta - 1)}{\beta} = CaO + 0{\cdot}394\ MnO - 0{\cdot}933\ SiO_2 - 1{\cdot}184\ P_2O_5 - 0{\cdot}916\ Al_2O_3 = (CaO')$$

which may be taken to represent the equivalent free lime concentration on a weight-percent basis, in which terms the other reactants were expressed.

Vajragupta's data cover the three temperatures 1550 ± 10° C., 1585 ± 10° C., and 1635 ± 10° C. As shown in Figs. 11*a–c* good correlations were obtained on plotting log $P_2O_5/[P]\ (CaO')^3$ against log $[O]_c$, the latter term representing the oxygen content of the metal as calculated from the slag composition and temperature. The average lines through these three sets of points were drawn to the same gradient,

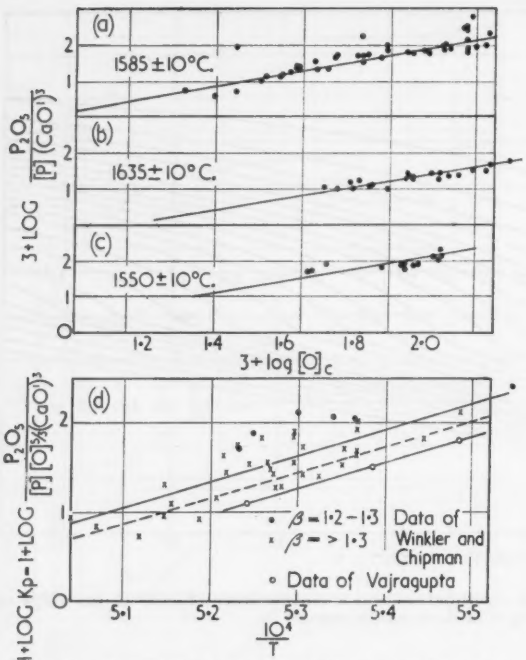

Fig. 11—Equilibria of the phosphorus slag/metal reaction, based on data of Vajragupta and Winkler and Chipman

5/3, and the equilibrium constant of the phosphorus reaction was taken to be:

$$K_P = \frac{(P_2O_5)}{[P]\,[O]^{\frac{5}{2}}\,(CaO')^3}$$

Using the equations of the lines of Figs. 11*a–c* the following values of log K_P were obtained for the three different temperatures:

	Temperature (T), °C.		
	1550	1585	1635
$\frac{10^4}{T}$	5·485	5·384	5·241
log K_P	0·8	0·5	0·1

A plot of log K_P against $10^4/T$ is shown in Fig. 11*d* and the appropriate values calculated from the data of Winkler and Chipman are also given. In the latter case, slags with values of β less than 1·2 have been omitted. For slags with values of β between 1·2 and 1·3 (shown by solid circles) K_P is high, and with values of β greater than 1·3 good agreement with the data of Vajragupta has been obtained. The variation of K_P is considered to be associated with the basic property of FeO itself which becomes an important factor at low values of β, an extreme example being the dephosphorization in the puddling process.

From Fig. 11*d* the line based on Vajragupta's data gives the equation:

$$\text{Log } K_P = \frac{28{,}570}{T} - 14{\cdot}87 \quad \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

which may be taken to represent dephosphorization with slags having a basicity value β greater than 1·7. For basicities in the region of 1·5 the equation becomes:

$$\text{Log } K_P = \frac{28{,}570}{T} - 14{\cdot}71 \quad \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

and the latter term reaches a value of approximately 14·4 when β is in the region of 1·3.

The use of the term $[O]^{\frac{5}{2}}$ is explained by the fact that the FeO in the slag exists in the form of simple (FeO) molecules and relatively stable $(FeO)_4$ molecules. The latter, being associated with $2CaO.SiO_2$, causes dephosphorization as well as the simple molecules, with the result that, depending on the fraction of $(FeO)_4$ molecules present, the oxygen term will vary between $[O]^{\frac{1}{2}}$ and $[O]^{\frac{5}{2}}$ and for basic steelmaking slags the value will normally lie at $[O]^{\frac{3}{2}}$.

As Maurer and Bischof[18] have suggested, the use of the term [P] and not $[P]^2$ may be explained on the basis that the phosphorus exists as a double molecule.

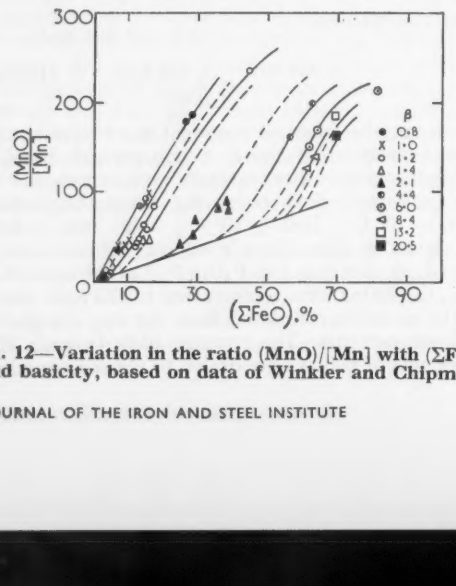

Fig. 12—Variation in the ratio (MnO)/[Mn] with (ΣFeO) and basicity, based on data of Winkler and Chipman

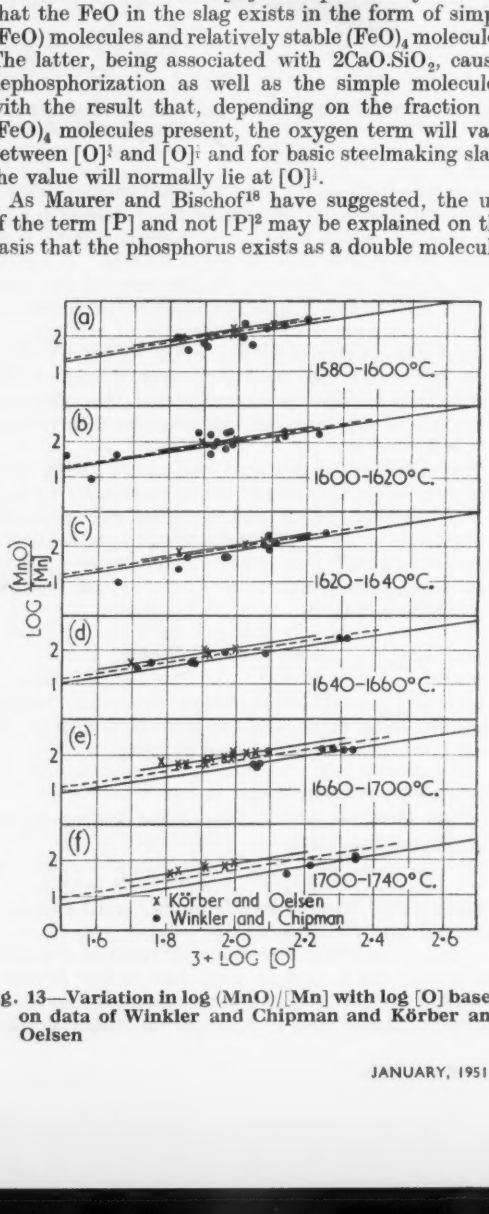

Fig. 13—Variation in log (MnO)/[Mn] with log [O] based on data of Winkler and Chipman and Körber and Oelsen

The Manganese Reaction

Figure 12, based on Winkler and Chipman's data, shows the variation in (MnO)/[Mn] with (ΣFeO) and with increasing values of β, the temperature range covered being 1550–1700° C. Although there is a considerable scatter of the points it is important to note that for each basicity there is a critical (ΣFeO) content above which there is a marked rise in the ratio (MnO)/[Mn]. This is to be expected from the foregoing argument on the influence of basicity on the oxygen content.

For the study of this reaction the data of Körber and Oelsen[5] were also used. In this case the oxygen content to the melt had to be calculated. The plot of log (MnO)/[Mn] against log [O] is shown in Fig. 13 and for comparison the results based on the data of Winkler and Chipman are also given. Certain criteria had to be satisfied, *viz.*:

(1) The average lines through the different sets of points should be parallel for both sets of data
(2) The lines should lie progressively lower with increasing temperature
(3) The points from one set of data should lie close to the points for the other set of data for the same range of temperature.

These criteria were readily satisfied, it being an easy matter to draw in each case the average line (shown dotted) between different sets of data. The agreement between corresponding sets of data becomes slightly less with increasing temperature, but this is to be expected and probably results from increasing differences in temperature measurement with increasing temperature. Furthermore, in Körber and Oelsen's work the temperatures were measured optically.

It should be mentioned that the gradient of each line was expected to be unity, but more satisfactory correlations were obtained by adopting the gradient 3/2.

From the equation of each average line representing different temperatures, the values of

$$\text{Log } K_{\text{Mn}} = \log \frac{(\text{MnO})}{[\text{Mn}]\,[\text{O}]^{1.5}}$$

were calculated with the following results :

t° C.	T	$\frac{10^4}{T}$	Log K_{Mn}
1590	1863	5·368	3·62
1610	1883	5·310	3·53
1630	1903	5·254	3·45
1650	1923	5·200	3·42
1680	1953	5·121	3·33
1720	1993	5·017	3·21

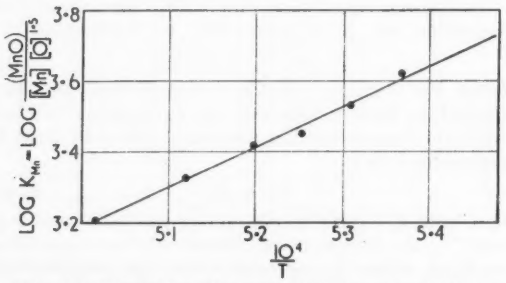

Fig. 14—Plot of log K_{Mn} and $10^4/T$ based on Fig. 13

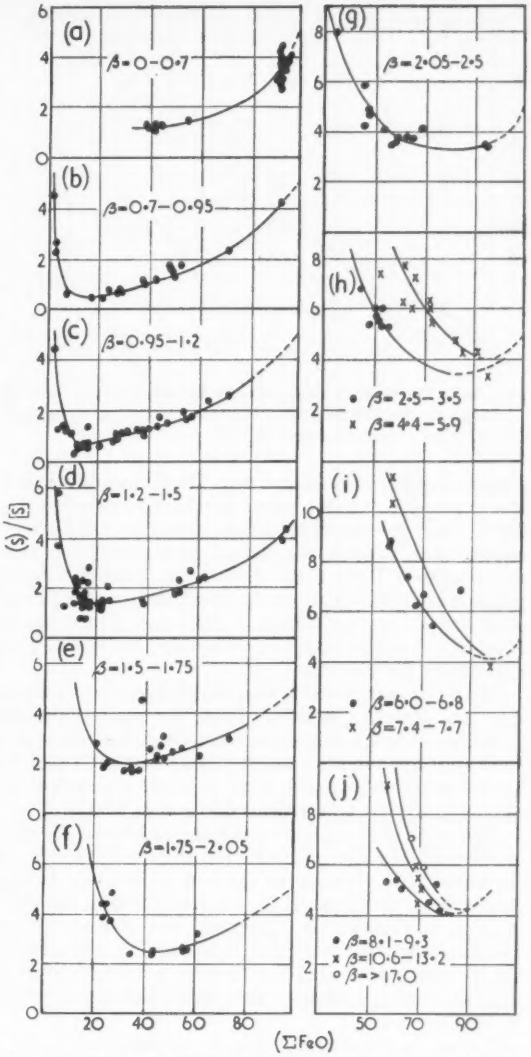

Fig. 15—Plot of (S)/[S] against (ΣFeO) for different ranges of basicity from data of Grant and Chipman

These results were plotted as shown in Fig. 14 and the variation in K_{Mn} with temperature was found to be :

$$\text{Log } K_{\text{Mn}} = \log \frac{(\text{MnO})}{[\text{Mn}]\,[\text{O}]^{1.5}} = \frac{11{,}540}{T} - 2{\cdot}585 \ldots (18)$$

The use of the oxygen content of the steel, instead of the term (FeO) in the slag, makes it unnecessary to consider the basicity of the slag, but the latter must be taken into consideration if the term (ΣFeO) is used instead of [O]. The index 1·5 may arise because (MnO) is itself a base and influences the oxygen content, but a simpler explanation would be that this index is a close approximation to the effect produced by the use of weight-percent concentrations instead of mol fractions and activity coefficients.

The Sulphur Reaction

Grant and Chipman[19] have intimated that the FeO in the slag has little, if any, effect on the partition of

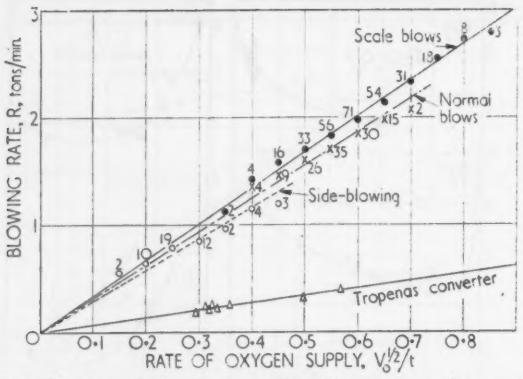

Fig. 16—Correlation between the blowing rate (tons of iron converted per minute) and the rate of supply of oxygen from the blast ($V_o^{\frac{1}{2}}/t$)

sulphur between metal and slag. They have developed the expression 'excess base,' in which is included the MgO, and by approximation methods they have shown that a good correlation exists between this expression and the ratio (S)/[S]. It is known from practical experience, however, that an increase in the FeO in the slag may cause a pronounced increase in the sulphur in the bath, and Schenck[20] has evolved an expression for this effect.

In the present work it was decided at the outset to use the β value, defined above, for expressing the basicity, because this expression contains the terms CaO and MnO and ignores the MgO content which in actual practice seems to have little, if any, effect on the ratio (S)/[S], apart from dilution of (CaO).

Figure 15 shows, on a weight-percent basis, the plot of (S)/[S] against (ΣFeO) for different ranges of basicity. The influence of the iron in the slag is certainly most pronounced (in contradiction to the conclusion of Grant and Chipman), and it points very definitely to the fact that there are two reactions. In the first, increasing FeO causes a marked drop in the partition coefficient and the following reaction probably occurs:

$$FeS + \begin{Bmatrix} MnO \\ CaO \end{Bmatrix} = FeO + \begin{Bmatrix} MnS \\ CaS \end{Bmatrix}$$

When (ΣFeO) rises above a certain critical value for a given β value the predominating reaction changes to one in which further increases in FeO improve the desulphurization, but this range is not normally encountered in practice, except perhaps in the case of certain rimming steels. This second reaction may involve oxidation of the sulphur in the slag by $(FeO)_4$ to SO_2 and $CaSO_4$, somewhat as follows:

$$2FeS + (FeO)_4 \rightleftharpoons 2SO_2 + 6Fe$$
$$CaS + (FeO)_4 \rightleftharpoons CaSO_4 + 4Fe$$

It is significant that, as has been shown above, the concentration of $(FeO)_4$ molecules or complex $Fe_2O_4^{-4}$ ions increases with basicity and, as is the case, the minimum value of (S)/[S] would be expected to move to the right with increasing basicity. However, the whole question is complicated by the fact that pure FeO slags have a considerable solubility for sulphur, and it would appear from Fig. 15 that the partition coefficient tends to a constant value of 5 as (ΣFeO) increases to 100%.

It is interesting to note that, at very low values of (ΣFeO), slags of low basicity should be quite efficient desulphurizers and even with slightly acid slags (β = 0·7–0·95), as shown by Fig. 15*b*, a sulphur partition of more than 3 : 1 is indicated. This is confirmed by the fact that blast-furnace slags with a CaO/SiO_2 ratio about unity and with approximately 1% (ΣFeO) have a (S)/[S] partition in the region of 7.

The excellent desulphurization obtained with electric-furnace reducing slags is well known, but it would appear that the presence of a small amount of calcium carbide is required to ensure the necessary low concentration of (FeO), and the very good desulphurizing property of the white electric-furnace slags.

BASIC BESSEMER PRACTICE

Basicity

There is an extensive literature dealing to some extent with the variation in the basicity of the slag in basic Bessemer practice. Bardenheuer and Thanheiser,[21] and later Bading,[22] suggest that during the foreblow the slag exhibits acid characteristics and at the flame drop there is a marked change to the basic condition. This contention is based on Tammann and Oelsen's[23] measure of basicity

$$100(CaO - 1{\cdot}18\ P_2O_5)/(CaO - 1{\cdot}18\ P_2O_5 + SiO_2),$$

but these writers are not clear on what constitutes an acid slag. Examination of their data using the β value defined above shows quite clearly that during the course of the blow the slag varies in basicity from β = 1·2 to β = 1·7.

In the discussion on Fairley's[6] paper on slag control, Mitchell[24] has shown that the V ratio, which is very similar to the β value, gives the best distribution curve for basic Bessemer slags, the mode lying at a V ratio of 2·0.

Conversion Rate

In an experimental campaign covering some 400 heats, and devised with a view to examine, among other things, the nature of the variation in the nitrogen content, consideration was given to the rate of blowing or conversion rate.

Theoretical Consideration—It is considered that the blowing rate depends primarily on the rate of FeO formation from the oxygen in the blast because of the large excess of liquid Fe, and that the secondary reaction would involve the FeO formed and the carbon, manganese, silicon, etc., of the bath.

In the reaction $Fe + \frac{1}{2}O_2 \rightarrow FeO$ the rate of FeO formation will, in all probability, be represented by:

$$r = k_1.Fe.O_2^{\frac{1}{2}} - k_2.FeO \quad \ldots\ldots\ldots\ldots (19)$$

Since Fe remains virtually constant and the FeO formed is largely removed by subsequent reaction with the accompanying elements, the rate may be represented by:

$$r = k_3.O_2^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots (20)$$

and, with k_3 expressed on a reciprocal time basis (*e.g.*, $min.^{-1}$), the rate of conversion should be proportional to $V_o^{\frac{1}{2}}/t$, where V_o represents the total oxygen from the blast, expressed in, say, 10^3 cu. ft.

Equation (20) is based on the fact that, in default of a method for expressing the oxygen concentration in terms of pressure and using the expression $r = k_3 P_{O_2}^{\frac{1}{2}}$ in a process where the oxygen is continuously supplied, the oxygen concentration must be related to the quantity of oxygen in contact with the given volume of metal, the latter being essentially constant.

Experimental Results—Figure 16, representing the average conversion rate R tons/min. for different ranges of oxygen supply rate $V_o^{\frac{1}{2}}/t$, confirms the above deductions. In Fig. 16 a comparison is made between three sets of data :

(1) Orthodox blowing with scale additions, with and without oxygen enrichment, and referred to as scale blows

(2) Orthodox blowing with and without oxygen enrichment, and referred to as normal blows

(3) Side-blowing scale additions or oxygen enrichment.

Further confirmation is given by the Tropenas converter data of Harrison, Newell, and Hartley,[25] which again shows that the conversion rate is directly proportional to the square root of the oxygen supply.

From Fig. 16 the equations connecting the rate of oxygen supply with the conversion rate R for the orthodox converter were found to be :

$$R = 3{\cdot}125\ V_o^{\frac{1}{2}}/t \text{ for normal blows} \quad \ldots\ldots\ldots(21)$$

$$R = 3{\cdot}360\ V_o^{\frac{1}{2}}/t \text{ for scale blows} \quad \ldots\ldots\ldots\ldots(22)$$

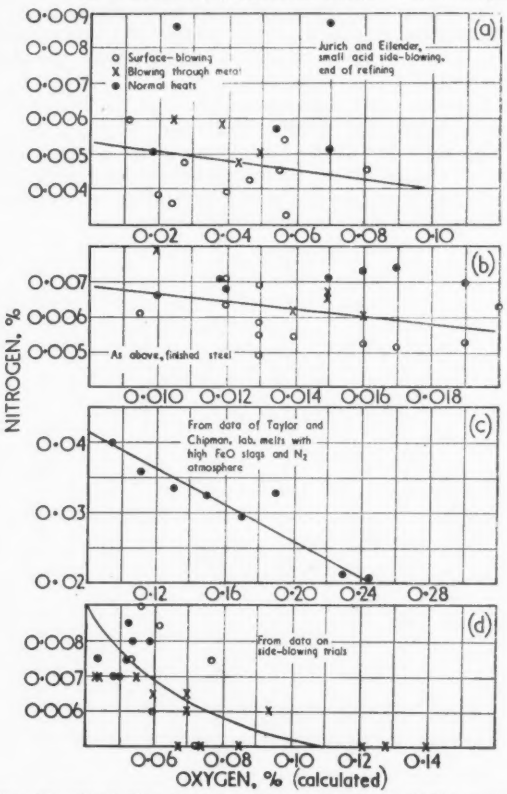

Fig. 17—Variation in the nitrogen content of the melt with the oxygen content based on data from different sources

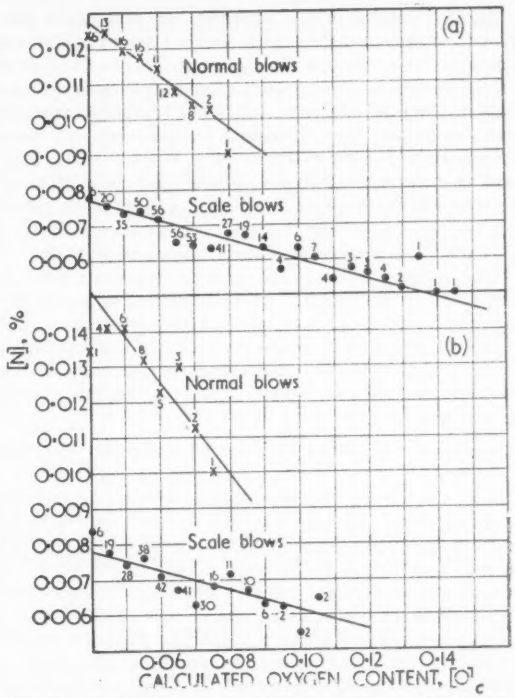

Fig. 18—Variation in the nitrogen content with the calculated oxygen content of the blown metal for two qualities of steel and two groups of data

The higher factor for the scale blows is the result of oxidation by the scale, the oxygen content of which was not taken into account in calculating the oxygen supply rate.

In Fig. 16 and subsequent diagrams the figure beside each point represents the number of results upon which the average is based.

The Nitrogen Reaction and Influence of the Oxygen Content of the Steel

The examination of the literature has revealed little information on the influence of the oxygen content of the steel on the nitrogen content. As shown in Figs. 17*a* and *b*, Jurich and Eilender[26] indicate, although the correlations are scarcely good enough, that with increasing oxygen content the nitrogen content of the steel tends to decrease. Confirmation of this point appeared after studying the data of Taylor and Chipman,[2] which covered laboratory melts with high FeO slags in a nitrogen atmosphere. In this case, Fig. 17*c*, the correlation, based on average nitrogen contents for different ranges of oxygen content, was particularly good, but the range of values differed considerably from that of Jurich, signifying that another factor, possibly the carbon content of the steel, also required consideration.

In Fig. 17*d* there is a definite trend showing a decreasing nitrogen content with increasing oxygen content, the latter having been calculated according to the method already given and based on side-blowing experiments carried out by the author using a 25-ton converter.

In the experimental campaign on 400 heats previously referred to, it was decided to examine the nature of the effect of the oxygen content of the steel on the nitrogen content and, since ample data on final slag and metal analyses and steel temperatures had been collected, the calculated oxygen contents were arranged in groups (0·03–0·04%, 0·04–0·05%, etc.) and the average nitrogen content for each of these groups was determined. Two sets of data, each covering normal blows and scale blows, were examined in this way, the four results being shown in Fig. 18.

The results grouped themselves approximately in the form of a straight-line correlation, undoubtedly significant in each case, the oxygen content of the steel (as calculated) in the case of the normal blows being about twice as effective as in the case of the scale-treated blows which had, of course, lower nitrogen contents.

Examination of Other Factors Affecting the Nitrogen Content

There is a very extensive literature on this subject and, in general, Dickie[27] and Kootz[28] have covered the subject fairly thoroughly. Since the oxygen content of the metal appeared to be an additional factor to be considered, it was decided to attempt an examination of the data by eliminating the effects of the various factors one after the other. By this method it should be possible to determine more precisely the effect of factors which might otherwise be hidden or distorted by a straightforward plot.

Eliminating the Effects of Different Factors

Taking the nitrogen content of the steel as the criterion, it is possible to correct for the influence of one of the major factors, as in the case of the oxygen content of the steel, and, after correcting each result to a standard oxygen content of, say, 0·06%, the new data can then be correlated with the second factor, say, temperature. In this way the effect of temperature can be obtained independently of its influence on the oxygen content of the steel. For example, the oxygen content of the steel under any given set of conditions increases with temperature, as does the nitrogen content; hence it is necessary to remove the effect of the oxygen content on the nitrogen before the true effect of the temperature can be obtained. It will be understood, of course, that this method replaces the method whereby steels with constant oxygen content would be selected before correlating nitrogen with temperature.

The method may be explained simply by assuming that there is a criterion N and that it is necessary to determine the influence of two factors O and T. The values of O are set in ranges such as 0–0·02, 0·01–0·03, 0·02–0·04, etc., and under each of these ranges are grouped the corresponding N values to cover all the data. Each of these groups is then averaged and N is plotted against O.

The correction for the influence of O on N is now carried out as follows. The gradient of the line obtained is determined and the corrected value N_O is given by the equation:

$$N_O = N + g(0{\cdot}06 - O)$$

where g is the gradient, 0·06 is a standard value adopted, and O is any particular value.

After correcting all the data to the new values of N_O, these are now used to determine the influence of the factor T, and on plotting the average values of N_O against T, the second correction can be applied from the formula:

$$N_T = N_O + h(5 - T)$$

where h is a new gradient and 5 is the standard value of T.

In a manner very similar to that described above and covering two sets of data, groups (a) and (b), the effects of steel temperature, rate of supply of air or blowing rate, weight of scale used, and bottom life on the nitrogen content of the steel were determined. Although other factors might to some extent influence the result, these major factors were clearly defined and were confirmed by the second set of data.

The influence of the oxygen content of the steel, as given in Fig. 18, has already been described, and the nitrogen contents for all the heats were recalculated to correct for the influence of varying oxygen contents in the steel, using the following equations:

$$[N]_O = [N]_m - 0{\cdot}075\ (0{\cdot}06 - [O]_c) \text{ for group } (a), \text{ normal heats} \quad (23)$$

$$[N]_O = [N]_m - 0{\cdot}130\ (0{\cdot}06 - [O]_c) \text{ for group } (b), \text{ normal heats} \quad (24)$$

$$[N]_O = [N]_m - 0{\cdot}029\ (0{\cdot}06 - [O]_c) \text{ for groups } (a) \text{ and } (b), \text{ scale heats} \quad (25)$$

where $[N]_O$ is the corrected nitrogen, $[N]_m$ is the minimum nitrogen content by chemical analysis, 0·06 is the adopted standard oxygen content of the steel, and $[O]_c$ is the oxygen content calculated from the slag analysis and the temperature.

Influence of Temperature—The new values of the nitrogen content of the steel, now referred to as $[N]_O$, were known to be influenced by temperature. Since the standard thermodynamic approach was more likely to give the better correlation, an equation of the following type was considered:

$$\text{Log}\,[N]_O = \frac{a}{T} + b$$

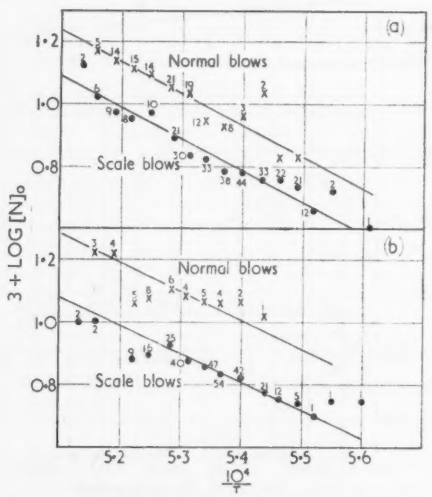

Fig. 19—Influence of temperature on the nitrogen content after removing the effect of variations in the oxygen content of the steel

Values of log $[N]_O$ were averaged for varying ranges of $10^4/T$ and, as shown in Fig. 19, good correlations were obtained in all four cases, the scale blows, with much more data available, giving highly significant correlations. As shown in the diagrams, the gradient was drawn exactly the same in each case and the equation for correcting for temperature was found to be:

$$(3 + \log [N]_{1600}) = (3 + \log [N]_O) - \left(5{\cdot}339 - \frac{10^4}{T}\right) \ldots (26)$$

where $[N]_{1600}$ now represents the nitrogen content after correcting to a standard oxygen content of 0·06% and a standard temperature of 1600° C.; 5·339 is the value of $10^4/T$ at 1600° C., and T is the absolute temperature. The integer 3 has been added to the logarithms simply to retain positive values and to reduce the amount of arithmetic.

In actual practice the effect of temperature will not be so marked as in Fig. 19, owing to the fact that, as the nitrogen increases with temperature, there will also be an increase in the oxygen content of the steel which will to some extent offset the nitrogen increase.

Influence of Conversion Rate—This was found by plotting the rate of oxygen supply from the blast, $V_o^{\frac{1}{2}}/t$, against the nitrogen content $[N]_{1600}$, the former being related to the conversion rate as shown by equations (21) and (22). The correlation between $V_o^{\frac{1}{2}}/t$ and $[N]_{1600}$ was carried out in the manner described above and, based on Fig. 20, the following equations were evolved for correcting to a standard rate of 0·6 for $V_o^{\frac{1}{2}}/t$:

$$\text{Log } [N]_R = \log [N]_{1600} - [\log 0{\cdot}6 - \log V_o^{\frac{1}{2}}/t] \quad \text{for normal blows} \ldots\ldots\ldots\ldots (27)$$

$$\text{Log } [N]_R = \log [N]_{1600} - \tfrac{1}{2} [\log 0{\cdot}6 - \log V_o^{\frac{1}{2}}/t] \quad \text{for scale blows} \ldots\ldots\ldots\ldots (28)$$

where $[N]_R$ is the nitrogen content of the steel after correcting to standard values of oxygen content, temperature, and conversion rate or rate of supply of oxygen from the blast.

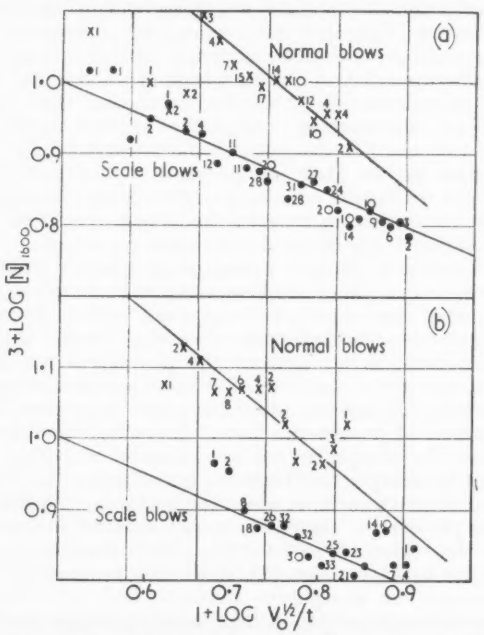

Fig. 20—Effect of conversion rate $V_o^{\frac{1}{2}}/t$ on the nitrogen content of the steel $[N]_{1600}$

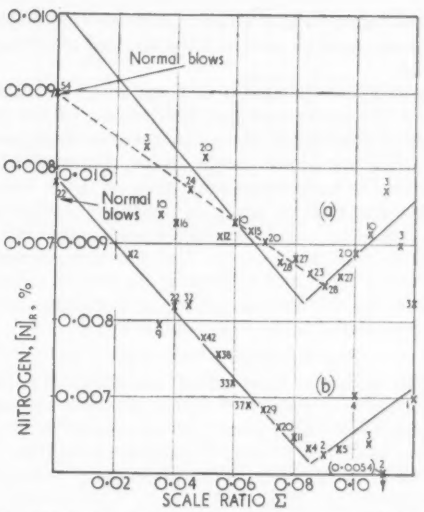

Fig. 21—Variation in the nitrogen content of the steel $[N]_R$ with varying scale ratio or scale per ton of iron

Influence of Scale Additions—The values of $[N]_R$ were now averaged for the various ranges of scale ratio (Σ tons of scale per ton of iron) for both groups of data and the results are plotted in Fig. 21. The data for normal blows in group (*a*) appear to be low at 0·009% average for $[N]_R$, but the correlation as given by the broken line appears to be satisfactory. The data in group (*b*), collected over a much shorter period of time and representing, more or less, a continuous series of blows, gave a much better correlation and, therefore, the gradient as represented by the full lines in each

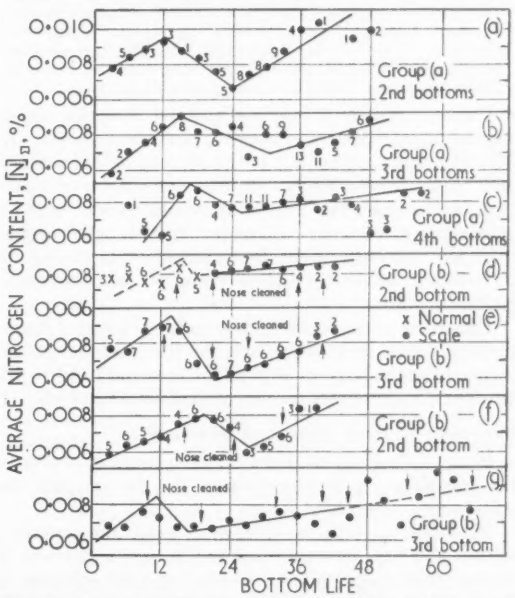

Fig. 22—Variation in the nitrogen content $[N]_\Sigma$ with bottom life or number of heats from the bottom

case was taken so that a common correction factor for scale ratio could be used and the amount of arithmetic reduced.

Above a scale ratio of 0·09 there was a considerable amount of scatter and the distribution of the points suggested that there was an increase in nitrogen content with the higher scale ratios. Consequently in correcting to a standard scale ratio of 0·06, values of Σ exceeding 0·1 for group (*a*) and 0·09 for group (*b*) were neglected. It is suggested that with very large additions the violence of the reaction causes the ejection of scale and a drop in its overall efficiency.

From Fig. 21 the correction for variations in scale ratio was found to be represented by:

$$[N]_{\Sigma} = [N]_R - 0{\cdot}048\,(0{\cdot}06 - \Sigma) \quad \ldots\ldots\ldots(29)$$

Effect of Bottom Life—After correcting all values for a standard scale ratio of 0·06 the nitrogen values, now referred to as $[N]_{\Sigma}$, were plotted against bottom-life ranges, as shown in Fig. 22, and covering the ranges 0–6, 3–9, 6–12, etc. Two interesting features are illustrated:

(1) The fact, already established,[27] that the nitrogen content increases with bottom life

(2) There is a marked increase in the nitrogen content during the first 12–20 blows, after which there is a definite decrease in nitrogen content before the curve again rises to the higher nitrogen values. The best explanation for the appearance of a maximum nitrogen value at 12–20 blows is considered to be as follows: At the beginning of a new bottom there is a relatively large amount of wear on the bottom and, therefore, a sudden increase in bath depth; hence the nitrogen increases rapidly. At the same time, since the volume of the converter is relatively small, there is a marked deposition of ejected material at the mouth of the converter and the constricted mouth area gives rise to higher nitrogen contents, the overall effect being a peak nitrogen content at some 12–20 blows. At this stage the mouth of the converter is generally cleaned and in many cases becomes actually larger than at the beginning of the campaign. Furthermore, since the bottom has, by this time, settled down to a more gradual rate of wear, there is a marked drop in nitrogen content followed by a general increase. Thereafter the nose again requires cleaning, but this becomes increasingly difficult and the nitrogen content tends to drop again, but with increasing uncertainty.

The plant records were examined and the times when nose-cleaning was carried out were noted. In Fig. 22 arrows are shown at the corresponding periods and these substantially confirm the effect of nose-cleaning as described above. It would appear that by maintaining a wide converter mouth the higher nitrogen contents might be reduced by anything up to 0·003%, other conditions being, of course, essentially constant.

Effective nose-cleaning becomes more and more difficult with increasing bottom life and, as is indicated particularly in Fig. 22*g*, the swing in nitrogen content became more pronounced after some 40 heats.

Summary of Basic Bessemer Reactions

In the following, the blow is understood to comprise the foreblow (up to the drop of the flame) plus the subsequent afterblow.

Oxidation of Silicon—Silicon is removed generally within the first two minutes and a rapid increase in temperature takes place. Lime goes into solution to form a slag which coats the remaining pieces of lime, and this semi-solid slag is slightly basic ($\beta = 1{\cdot}2$–$1{\cdot}3$). With high-silicon iron (1% of silicon) a foaming slag which is almost fluid is formed as the silicon oxidizes and the undissolved lime is largely broken up into small pieces.

Oxidation of Manganese—This is considered to aid the formation of slag in the early stages, the manganese oxidizing a little less rapidly than the silicon, but depending, of course, on relative concentrations. According to the basicity and the concentration of MnO in the slag, a certain amount of manganese is unoxidized and remains at a fairly steady value throughout the period of carbon removal. During the afterblow the manganese content of the bath increases again, corresponding with the maximum rate of phosphorus removal when part of the FeO and MnO in the slag is reduced in the formation of P_2O_5.

Carbon Removal—During the early stage of the blow, when silicon is being oxidized, only a small portion of carbon is removed, and when the former is completely oxidized and the manganese has been reduced to a comparatively low value the oxygen in the blast is almost entirely utilized in the removal of carbon. Consequently, over the greater part of this period the rate of carbon removal is virtually constant and shortly before the flame drop the carbon concentration falls off exponentially as the FeO in the slag rises and phosphorus removal becomes appreciable.

Phosphorus Removal—A small amount of phosphorus is oxidized during the early stages of the blow when the temperature is low, but the basicity and FeO content of the slag are not sufficiently great to permit the removal of large amounts of phosphorus. The latter remains at a steady value over the greater part of the blow, but at the flame drop, when the carbon has been largely removed, the FeO content of the slag increases to a point when appreciable dephosphorization sets in and the major portion of the lime is fluxed. Thereafter the removal of phosphorus is vigorous and reaches a maximum rate when part of the FeO and MnO of the slag is utilized in the oxidation of phosphorus. At this particular period the total oxygen consumption is roughly twice that supplied by the air. For example, if the normal supply of oxygen in the blast is equivalent to 0·6% of the charge weight per minute, then during the maximum rate of phosphorus removal the oxygen consumption is roughly 1·2% of the charge weight per minute.

The rate of phosphorus removal diminishes rapidly towards the end of the blow and the FeO content of the slag rises rapidly to correspond with a marked improvement in the fluidity of the slag, the end of the blow being determined by the phosphorus content required in the final steel. The rapid increase in temperature during the afterblow tends to oppose the removal of phosphorus, but at the end of the blow, when the phosphorus has been reduced to 0·06% or less, the temperature begins to fall off and with a slag of sufficient basicity in which the FeO is rising rapidly, the phosphorus content is readily reduced to values in the region of 0·02–0·03%. With finishing slags of low basicity a high FeO in the slag is necessary to provide low phosphorus contents and this effect becomes exaggerated at high finishing temperatures.

Variation in Nitrogen—At the beginning of the blow and particularly with iron having a high nitrogen

content, there is usually a small reduction in nitrogen and this corresponds with a period during which the carbon is little affected, whilst the oxygen content of the melt increases slightly. During the period of carbon removal the temperature and the oxygen content of the bath rise slightly and the nitrogen content, in general, shows a gradual increase. If scale has been added the oxygen content of the bath will rise rapidly above the equilibrium concentration and the nitrogen content will be effectively reduced.

During the afterblow the nitrogen content rises rapidly and there is a marked increase in the temperature and a considerable reduction in the oxygen content of the metal. If scale has been added at, or shortly before, the flame drop, the FeO in the slag and the oxygen content of the bath during the afterblow remain at higher values, and consequently the tendency for the nitrogen to increase is opposed.

The cooling effect of the scale is also a factor tending towards a reduction in nitrogen content which can be achieved to a lesser extent by the judicious use of scrap additions during the blow and by control of the temperature. A possible further effect of scale or scrap additions before the afterblow is that the consequent reduction in temperature favours earlier phosphorus removal and slows up carbon removal, with the result that the afterblow period is reduced somewhat and the carbon × oxygen product, being higher, tends to prevent nitrogen absorption.

The nitrogen content of the bath is also reduced somewhat by concentrating the tuyeres over a smaller area of the bottom, increasing the total tuyere cross-sectional area, or making smooth-wall tuyeres. These factors increase the rate of oxygen input for a given zone or metal volume in the bath and, as already described, the nitrogen content decreases with increasing rate of oxygen input which, no doubt, increases the oxygen concentration in the particular zone of the bath.

Variation in Sulphur Content—At the beginning of the blow the sulphur content of the metal decreases appreciably. This is considered to be due to the development of the initial slag which, although only slightly basic, has a low FeO content and favours desulphurization, the partition coefficient (S)/[S] being high. As the basicity of the slag increases, the sulphur in the metal continues to decrease until the FeO in the slag builds up to a value at which sulphur reversal occurs. This reversal continues slowly during carbon removal until the flame drop, when the rapid solution of lime and the marked reduction in FeO in the slag cause an appreciable desulphurization again.

This general scheme of sulphur variation is affected by the manganese content of the iron; if it is high the subsequent reversal is not so marked and the heat finishes at a lower sulphur content. Furthermore, if the sulphur content of the lime used is high the initial and final desulphurization effects will be less apparent, and if a large addition of low-sulphur lime is used the final desulphurization will be more marked.

BASIC OPEN-HEARTH PRACTICE

The theory of basicity and oxidation outlined above should find ready application in basic open-hearth practice, except where a sulphur problem exists as the result of poor fuel or a high sulphur content in the charge, in which case the practice has to be suitably modified. From the point of view of fuel economy and rapid working it is essential to establish a system of slag control leading to minimum slag volumes, rapid refining, and economy in the use of fluxes. When sulphur removal has to be the main consideration, large slag volumes and highly basic slags are usually necessary and the resulting loss in melting and refining speed and the higher consumptions of lime, scale, and spar render this practice much more costly. It is perhaps a truism to add that the most expensive material going into an open-hearth furnace is sulphur.

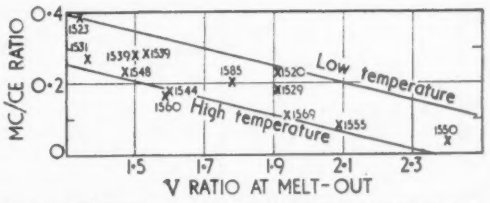

Fig. 23—Influence of slag basicity on the melt-out carbon, expressed as melt-carbon/carbon-equivalent of charge

The Variation in Slag Basicity

Slag Basicity at Tap—Assuming the absence of a sulphur problem, the slag basicity at tapping should be as low as possible, consistent with the removal of phosphorus to the specified value. With a relatively low basicity the FeO in the slag is more active, and refining can be completed with a low iron content in the slag.

The factors largely determining the total iron content of the slag and the oxygen content of the metal at tapping are:

(1) Temperature
(2) Carbon content
(3) Final rate of carbon removal
(4) Basicity of the tapping slag.

In general, the open-hearth refining technique today might be said to consist of fixing definite values for (1), (2), and (4), hoping for the best with regard to the total iron in the slag, and leaving (3) to look after itself.

Slag Basicity at Melt-Out—After making due allowance for the bank erosion during melting, the charge limestone and/or lime should be fixed to give melt-out values of β in the range 1·3–1·8, as within this range it is possible to estimate the V ratio within $\pm$ 0·1 by visual examination of slag pancakes. For values of V greater than 2·0 it becomes increasingly difficult to 'read' the slag pancakes accurately.

Another disadvantage of a high basicity at melt-out is the accompanying low melt-out carbon. This is illustrated in Fig. 23, which is based on the examination of data from a 100-ton tilting furnace. The ratio MC/CE is the melt-carbon/carbon-equivalent of the charge and represents the melt-out carbon for a given total of the accompanying elements C, Si, Mn, and P, all in terms of carbon equivalent; this ratio is plotted against the V ratio at melt-out. The effect has been confirmed on several occasions, but cannot be explained in terms of the theory of basicity and oxida-

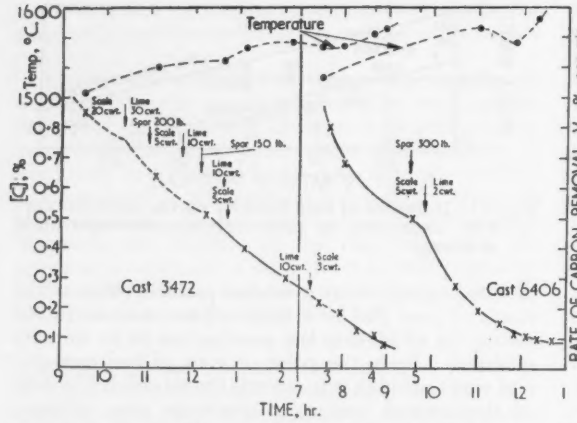

Fig. 24—Open-hearth refining curves, showing the effect of scale additions

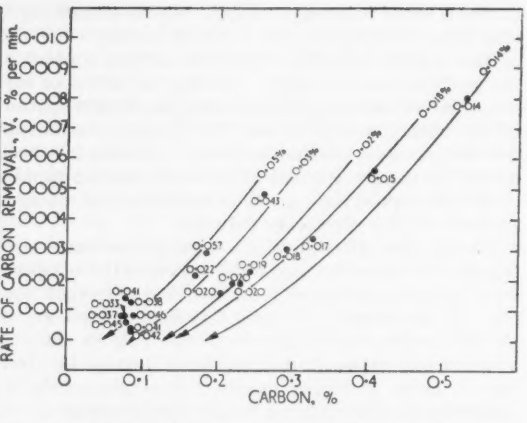

Fig. 25—Variation in refining speed with carbon content and the iso-oxygen contents

tion already described. In all probability it is to be associated with the longer melting period and loss of carbon by oxidation when large amounts of charge limestone and/or lime are used.

Refining Slags—It is considered an advantage to be able to add all the feed lime during the early part of refining, but this depends on several factors, chief among which are the temperature of the bath and the slag volume. Wherever possible, however, the refining slag should be brought to the predetermined composition as soon as possible so that full control during the refining period may be obtained. With a good system of slag control in operation this can be achieved.

Refining and Oxidation Technique

As illustrated in Fig. 24, the variation in carbon with time for an open-hearth heat may be represented by a smooth curve when sudden changes due to large additions of scale or lime or appreciable variations in temperature are avoided. For a given furnace working smoothly, therefore, it should be possible to draw the characteristic curve after, say, four carbon determinations, and to predetermine the time at which the carbon will reach the required value at tapping. For this purpose it will be necessary to keep the basicity and the FeO content of the slag at reasonably steady values or both increasing gradually, which is possible with a good system of slag control, and to maintain a fairly standard rate of temperature increase as the carbon content decreases.

From a series of open-hearth heats made under these conditions the refining rate, V_c, (percentage of carbon per minute) has been calculated by drawing tangents to the curves at the respective carbon contents. The results are shown in Table I, which also includes the basicity values β, the total iron content

Table I

BASICITY AND OXIDATION DATA FOR OPEN-HEARTH HEATS

Cast	V_c	β	(ΣFeO)	Temp., °C.	[C]	$[O]_a$	$[O]_c$	$[C][O]_a$	$V = 2[C]^3[O]_a$
4264 (1)	0·0080	1·91	15·2	1537	0·530	0·014	0·033	0·00742	0·0077
(2)	0·0051	2·11	14·3	1552	0·408	0·015	0·032	0·00612	0·0050
(3)	0·0033	2·38	13·6	1577	0·325	0·017	0·030	0·00553	0·0036
(4)	0·0030	2·75	14·3	1578	0·292	0·018	0·029	0·00526	0·0031
(5)	0·0022	3·02	15·0	1593	0·241	0·019	0·031	0·00458	0·0022
(6)	0·0019	3·03	15·6	1594	0·220	0·020	0·032	0·00440	0·0019
(7)	0·0015	3·18	16·2	1595	0·204	0·020	0·032	0·00408	0·0017
2958 (4)	0·0048	2·69	11·2	1594	0·262	0·043	0·027	0·01126	0·0059
(5)	0·0029	2·80	12·4	1599	0·184	0·057	0·029	0·01048	0·0039
(6)	0·0025	2·73	12·8	1600	0·165	...	0·030	...	...
6361 (4)	0·0024	2·72	14·8	1605	0·147	...	0·032	...	...
(5)	0·0012	2·84	17·6	1617	0·085	0·038	0·044	0·00326	0·0006
6369 (1)	0·0036	2·33	13·6	1540	0·232	...	0·028	...	...
(2)	0·0021	2·43	14·8	1550	0·172	0·022	0·030	0·00380	0·0013
(3)	0·0008	3·28	17·9	1600	0·091	...	0·039	...	...
6372 (2)	0·0019	2·15	10·5	1565	0·230	0·020	0·026	0·00460	0·0021
(4)	0·0008	2·95	16·8	1635	0·078	0·033	0·045	0·00258	0·0004
6375 (4)	0·0018	3·04	12·7	1590	0·200	...	0·020	...	...
6403 (4)	0·0014	2·81	15·7	1625	0·079	0·041	0·029	0·00324	0·0005
6406 (6)	0·0004	3·33	22·1	1615	0·084	0·041	0·039	0·00345	0·0006
6409 (5)	0·0008	2·80	17·4	1602	0·088	0·046	0·029	0·00405	0·0007
6412 (5)	0·0008	2·64	13·6	1588	0·074	0·037	0·022	0·00274	0·0004
6415 (7)	0·0003	2·40	13·9	1610	0·084	0·042	0·036	0·00353	0·0006
6418 (5)	0·0006	2·57	16·1	1597	0·079	0·045	0·039	0·00356	0·0006

of the slag (ΣFeO), the temperature of the metal, the carbon content, the oxygen content based on the alumina determinations of aluminium-killed bomb samples, and the calculated equilibrium oxygen content $[O]_c$ of liquid Fe based on the slag analysis.

In the case of heat 4264 the $[O]_c$ values are considered accurate, the slags having been analysed for Al_2O_3 and as no spar was used. In most cases, as would be expected, $[O]_c$ exceeds the analytical value because of the reaction with carbon.

It would appear that the activity of the FeO in the slag remains essentially constant during refining at approximately 0·030/0·229 or 0·131 for heat 4264. This is to be expected from the argument that $[O]_c$ would represent the final oxygen content if the carbon were boiled out and essentially pure liquid Fe resulted.

In Fig. 25 the variation in refining speed with carbon content is given. The oxygen content by analysis $[O]_a$ is shown beside each point, and from the equilibrium values on the x axis iso-oxygen contents are drawn to correspond. These lines suggest that the rate of carbon removal might well be proportional, not to the carbon content [C], as is generally accepted, but to $[C]^2$ or perhaps some other power. The data are, however, insufficient to establish this point with any certainty, but it is interesting to note that on plotting the rate of carbon removal V_c against the product $[C]\,[O]_a$, as shown in Fig. 26 for cast 4264, a curve is obtained. If the rate of the reaction is assumed to increase slightly with increasing temperature, the line would become more curved and would move towards the position indicated by the broken line, again indicating that the rate of carbon removal is not proportional to the simple carbon × oxygen product.

The rate of carbon removal is shown plotted against the product $[C]^2\,[O]$ in Fig. 26, and although the result might be somewhat fortuitous, it would appear that the rate of carbon removal might well be represented by the expression :

$$V = 2\,[C]^2\,[O]$$

in which case the reaction is probably of the third order and the velocity constant is approximately equal to 2. It should be pointed out that further

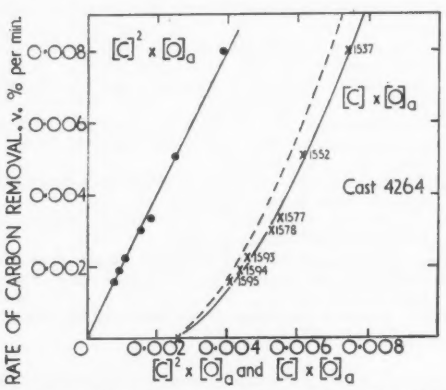

Fig. 26—Rate of carbon removal plotted against [C] [O] and $[C]^2$ [O] for cast 4264

confirmation of this point is required on a larger amount of precise data similar to cast 4264.

This would explain why Schenck[14] found the reaction velocity varied with carbon content and why, after correcting for this variation, the oxygen content of the bath could be determined with reasonable accuracy from the rate of carbon removal as, for example, has been described by the author[29] with reference to the refining of high-phosphorus iron.

It should perhaps be added that there are probably other factors which influence the rate of refining. It is known that the boil in the open-hearth furnace decreases noticeably during reversal when the fuel is off, and it is probable that the hearth area per ton will influence the rate of oxidation of the bath.

In conclusion, it is suggested that for a thorough study of the factors influencing the rate of carbon removal the work should be carried out on a laboratory scale since errors are introduced in the open-hearth furnace by the following :

(1) The carbon and oxygen contents of the bath appear to vary from top to bottom
(2) The boil is most vigorous where the flame strikes the bath
(3) The slag temperature may be anything from 30° to 100° C. above the metal temperature.

CONCLUSIONS

For more precise purposes the basicity of a slag may be represented by the expression :

$$\beta = \frac{CaO\% + 0{\cdot}394\,MnO\%}{0{\cdot}933\,SiO_2\% + 1{\cdot}184\,P_2O_5\% + 0{\cdot}916\,Al_2O_3\% + 0{\cdot}359\,CaF_2\%}$$

This value of basicity determines, with the temperature, the activity of the FeO in the slag, and the nature of the variation is such that the presence of $(FeO)_4$ molecules or $Fe_2O_4^{4-}$ ions may be assumed, the dissociation constant of these complex molecules or ions being in all probability a function of the concentration of $2CaO.SiO_2$ in the slag.

The relation between the FeO content of liquid Fe and the total FeO content of the slag at 1600° C. is given by the expression :

$$4\frac{(C_1)^4}{(L)} + D\frac{(C_1)}{(L)} = DC_2$$

where C_1 is the [FeO]%, C_2 represents (ΣFeO)% in the slag, L is the partition coefficient for simple (FeO) molecules, and D is the dissociation constant for the reaction $(FeO)_4 \rightleftharpoons 4\,(FeO)$, decreasing with increasing basicity. This expression holds for all basic slags except at low (ΣFeO) concentrations caused in all probability by compound formation between CaO and Fe_2O_3 and $2CaO.SiO_2$ and $(FeO)_4$. There is, of course, a deviation at high (ΣFeO) concentrations as the oxygen content of the liquid Fe tends towards the saturation value.

Oxygen contents calculated according to the foregoing theory correspond quite well with calculated values in the case of the phosphorus reaction, for which the equilibrium constant is given by :

$$\text{Log } K_P = \log \frac{(P_2O_5)}{[P]^2\,[O]^5\,(CaO')^3} = \frac{28{,}570}{T} - 14{\cdot}87$$

the last term varying with β and representing in this case values exceeding 1·7. For basicities in the region

of 1·5 the final term becomes 14·71 and when β is about 1·3 the value becomes approximately 14·4. The use of the index 5/3 is explained by the presence of (FeO) and $(FeO)_4$ molecules.

Calculated oxygen contents and analytical values have been compared for the manganese reaction with very successful results, the expression for the equilibrium constant being:

$$\text{Log } K_{Mn} = \log \frac{(MnO)}{[Mn]\,[O]^{1.5}} = \frac{11{,}540}{T} - 2{\cdot}585$$

The FeO content of the slag has a pronounced influence on the partition coefficient (S)/[S] and indicates reactions of the type:

$$FeS + CaO = FeO + CaS$$
$$CaS + (FeO)_4 = CaSO_4 + 4Fe$$

predominating at values below and above the critical (ΣFeO) content.

The rate of conversion (tons per minute) of a basic Bessemer heat would appear to be represented by the expression:

$$R = k\,V_o^{\frac{1}{2}}/t$$

where V_o is the total oxygen consumed and t is the blowing time.

The oxygen content of the liquid Fe is an important factor influencing the nitrogen content and this is borne out by the calculated oxygen contents of some 400 basic Bessemer heats, a greater reduction in nitrogen with increasing oxygen content being obtained with the normal heats which have a higher nitrogen content.

Temperature, conversion rate, and bottom life are confirmed as being important factors in the reduction of the nitrogen content of basic Bessemer steel.

In open-hearth steelmaking a high slag basicity at melt-out is to be associated generally with a low melt-out carbon, the effect probably arising as the result of a longer melting period.

The calculated oxygen content $[O]_c$ may be taken to represent the activity of the FeO in the slag or the final oxygen content of the liquid Fe, were the carbon boiled out, and it is probable that this value remains fairly steady during a period of 'smooth' refining.

The rate of carbon removal appears to depend on the product $[C]^2\,[O]$. Further data of a precise nature are required to establish this point, but it would appear that the rate of carbon removal in the basic open hearth might be represented by the expression:

$$V = 2[C]^2\,[O]$$

and the possibility that the reaction is of the third order and largely independent of temperature should not be overlooked.

Acknowledgments

The author wishes to express his gratitude to Mr. W. C. Bell for his interest and encouragement; to the production and research staffs of Messrs. Stewarts and Lloyds, Ltd., for their valuable assistance in carrying out the large-scale experimental work, and to the Directors of that company for permission to publish the results.

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Sigma-Phase in the Co–Cr and Fe–Cr Systems

By G. J. Dickins, Audrey M. B. Douglas, and W. H. Taylor

X-RAY powder patterns of the σ-phase of the Fe–Cr system have been published by many investigators, for example, Duwez and Baen.[1] The patterns differ somewhat in the number of lines recorded, their exact positions, and their relative intensities, and these variations are in accordance with the observations of Bradley and Goldschmidt.[2] Several Fe–Cr alloys of compositions near 50 at.-% Cr were therefore studied. A powder pattern characteristic of the σ-phase was identified, after making allowance for extra lines (occurring on some of the photographs) caused by either the α-phase or Cr_2N or both. The lines of this σ-pattern could be indexed fairly satisfactorily on the basis of an assumed hexagonal cell with $a = 16{\cdot}664$ kX. and $c = 8{\cdot}785$ kX., but the agreement between observed and calculated values of $\sin^2\theta$ was not very good. This attempt to determine the cell and symmetry may be compared with the attempts of Duwez and Baen,[1] who suggested a tetragonal unit cell with $a = 6{\cdot}196$ kX. and $c = 9{\cdot}058$ kX., and of Pietrokowsky and Duwez,[3] who proposed an orthorhombic unit cell with $a = 8{\cdot}66$ kX., $b = 6{\cdot}21$ kX., and $c = 5{\cdot}18$ kX. In neither case was the agreement between observed and calculated values of $\sin^2\theta$ better than for the assumed hexagonal unit cell.

It was obviously necessary to use single-crystal methods to establish, with certainty, the symmetry and unit cell of the σ-phase. Powder photographs of a Co–Cr alloy* containing 53·3 wt.-% Cr showed that the alloy as a whole consisted of the σ-phase,[4] and from this alloy single crystals of dimensions approximately 0·3 mm. were obtained. Laue oscillation and Weissenberg photographs showed that the symmetry is tetragonal,† with unit cell $a = 8{\cdot}79$ kX. and $c = 4{\cdot}55$ kX., and possible space groups $P\,4/mnm$, $P\,4mn$, or $P\,\bar{4}n2$, reflections $0kl$ being absent when $(k + l)$ is odd. It was then possible to index the powder pattern of σ-FeCr on the basis of a similar cell, with $a = 8{\cdot}790$ Å. and $c = 4{\cdot}559$ Å.; the same systematic absences are observed, hence the possible space groups are the same. The density of σ-FeCr was found to be 7·625 g./c.c., so that this cell contains 30 atoms. This correlation of powder and single-crystal data for σ-FeCr and σ-CoCr having established the cell and symmetry, the collection of intensity data was begun, using CoCr single crystals, with the intention of applying the usual Patterson and Fourier methods to find and refine the structure of these apparently completely isomorphous phases.

Manuscript received 28th November, 1950, from the Crystallographic Laboratory, Cavendish Laboratory, Cambridge.

Dr. Taylor is University Reader in Crystallography, Dr. Douglas is University Demonstrator in the Department of Mineralogy and Petrology, and Mr. Dickins, a research student in the Crystallographic Laboratory, is the holder of a BISRA Bursary.

* Supplied by A. G. Metcalfe, of the Department of Metallurgy, University of Cambridge.

† Certain small discrepancies in the intensities, observed with CuK_α radiation, are probably due to the high absorption in an irregularly shaped specimen.

At this stage, the authors were informed of the preliminary results obtained by Tucker[5] for a U–Cr alloy containing 1·4 at.-% Cr, identical in structure (according to Tucker) with β-U. This structure is tetragonal; the dimensions of the unit cell (which contains 30 atoms) correspond closely with those of σ-FeCr (allowance being made for the difference in size of the atoms), and the possible space groups are the same. The powder pattern of Tucker's material also shows the characteristic groups of strong lines seen in the σ-pattern. Calculation on the basis of the structure proposed by Tucker for β-U, based on $P\,4mn$, gave excellent agreement with the eye-estimated intensities observed for all of the first 30 possible reflections at the low-angle end of the σ-FeCr powder pattern. The structure proposed by Tucker is strongly pseudo-hexagonal along the (tetragonal) c-axis, and this pseudo-symmetry is clearly seen in single-crystal photographs of σ-CoCr. The β-U is said to be hard and brittle—properties which are also characteristic of the σ-phase.

It thus seems extremely probable that the σ-structure is essentially that proposed by Tucker for β-U. Full confirmation must await further work by Tucker, and our refinement of the σ-structure. The possibility of a lower symmetry than that of $P\,4mn$ cannot be excluded, nor is it inconceivable that the structure may include interstitial atoms. The σ-phase in other alloys (FeV, CoV, NiV, and FeMo[6]) is also under examination; in the FeMo alloy it should be possible to detect any ordering of the atoms.

Consideration of the possible relationship of the structure with the body-centred cubic α-Fe structure, or with the α-Mn structure,[2] must await a more detailed discussion. When accurate bond lengths and electron distributions have been determined, it will be of the greatest theoretical interest to consider the relationships between the σ-phase and β-U.

Acknowledgment will be made, in a more detailed publication, of help received from many colleagues. The authors thank Mr. D. A. Oliver, Director of Research, the B.S.A. Group Research Centre, Sheffield; also Mr. C. W. Tucker, Jr., of the G.E.C. Knolls Atomic Power Laboratory, Schenectady, New York, for his co-operation in making available to us, before publication, the full details of his β-U structure.

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DISCUSSION ON PAPERS

DISCUSSION AT MEETINGS · WRITTEN CONTRIBUTIONS

Correspondence on the Paper—

TESSELLATED STRESSES—PART V*

By F. László

Dr. **M. L. V. Gayler** (formerly at the National Physical Laboratory) : There are one or two facts which I would like to place before the author which may cause him to qualify the deduction he has drawn on precipitates in copper–aluminium alloys (p. 18).

The author's interpretation of the character of the precipitate from my published photomicrographs[7]† is incorrect : *seven days*' ageing at 130° C. does not reveal a *visible* precipitate ; the etching reagent has developed etching pits in those regions where segregation of the copper atoms has occurred in the matrix. This is very clearly seen in Fig. 20 of my paper.[7] Hence there is no evidence for the author's statement (p. 18), " They appear to be spheres which are spreading into the shape of cylinders." Furthermore, he deduces that "since $G_{Cu} > G_{Al}$, and the first phase of formation of these ordinary precipitates must take place without yield of either matrix or precipitate, a compact, *viz.*, spherical, shape should develop at some early stage." There is no microscopic evidence to support this statement ; rather the reverse, because the formation of the precipitate takes place *with* yield of the matrix. My researches have led me to conclude that the strains set up in the matrix by the segregation of the copper atoms are ultimately relieved by the precipitation of copper-rich aggregates and by the simultaneous recrystallization of the matrix associated with the segregate. Such areas will be seen in Figs. 1, 9, and 16 of my paper published in 1946.‡ The shape of the copper-rich constituent must not be deduced from these photomicrographs, but the size of these etching ' pits ' should be taken as a measure of a marked electrochemical reaction which is set up when particles of nearly pure aluminium (the recrystallized matrix) and copper-rich particles co-exist in the presence of the etching reagent.

In the early stages of ageing, *i.e.*, up to the second maximum hardness, it is impossible to decide the shape of the precipitate, since microscopical particles of precipitate are vigorously attacked by the etching reagent and ' pits ' are developed. It is only after maximum hardness has been passed that the precipitate is actually visible, *i.e.*, when the beginnings of the Widmanstätten structure are first observed as tiny rods on crystallographic planes.

Dr. László also remarks, " As a point of interest, . . . it may be mentioned that X-ray evidence of the ' infinitesimal ' lamellar start of precipitation is missing at 300° C." From the time/hardness curves it is obvious that the existence of the ' lamellae ' can only be very short, the growth to the needle stage being extremely rapid and probably taking place within a few minutes of ageing.

Dr. **E. Orowan** (Cavendish Laboratory, Cambridge) : Dr. László makes the interesting suggestion that the atomic rows in the slip direction may suffer a kind of buckling on the compressive side of a dislocation. An axially compressed thin rod, embedded in a much softer medium, is exposed to the danger of buckling ; it seems very doubtful, however, whether the close-packed atomic rows in a crystal behave like hard rods in soft surroundings. Even an ideally regular row of single atoms will expand transversely on axial compression owing to the deformation of the electron shells ; if the row is embedded in a crystal, therefore, its compression will create a lateral pressure which counteracts the tendency to buckling. That this pressure is considerable can be recognized from the fact that the elastic moduli of metal crystals in different directions differ only by factors of order unity. In addition, the close-packed rows will in reality have a rather loose irregular structure caused by thermal movement. For these reasons it would be very surprising if the effect considered by Dr. László exerted a significant influence upon the structure of the compressed side of dislocations ; the question could only be decided by a quantitative investigation.

AUTHOR'S REPLY

Dr. **László** wrote in reply : Dr. Gayler's comments make it necessary to add a few considerations, which were omitted from Part V. This gives a welcome opportunity to refer also to some most relevant experimental results which were published after the writing of Part V.

Precipitates are, in general, mono-crystalline as well as the individual crystal which is their actual matrix. If the strain energies associated with different shapes of precipitates are to be considered and compared with one another correctly, this point must not be neglected in cases of either elastic precipitation or plastic precipitation.

* *Journal of The Iron and Steel Institute*, 1950, vol. 164, pp. 5–26.

† The reference numbers refer to those used in the paper (p. 26).

‡ *Journal of the Institute of Metals*, 1946, vol. 72, p. 243.

The mono-crystalline solution has been derived only for the elastic lamellar precipitation, by Nabarro.[1] As a next step the generalized problem of the elastic cylindrical precipitation has been analysed, on a mono-crystalline basis, in an M.A. thesis recently completed in the Mathematics Department of Melbourne University, Australia. This work and that of Nabarro were confined to cubic crystals. Such mono-crystalline investigations would be desirable also for the elastic spherical precipitation as well as for plastic precipitation of all three types.

Considering elastic precipitation only, the conventional analysis for both the random and the mono-crystalline varieties is unsuitable for high misfit values. When enormous strains are imposed on a crystal lattice, and plastic strain cannot develop, the usual random or mono-crystalline elastic constants cannot be used in the regions of high super-elasticity. This condition occurs also when copper precipitates from an aluminium-base matrix ; the misfit amounts to 10·7%. Very high misfit values, greater than 45%, are encountered when graphite is rejected from a ferrous matrix. The analytical consideration of these values represents a formidable task for a mathematical atomic physicist.

The question of super-elasticity is not as simple as it has been presented in Part V. Bragg[4] showed that if a flat piece of monocrystalline material of thickness t is subjected to the shear stress f_s in its plane, which is supposed to be a potential slip plane, and the direction of f_s is supposed to be a potential slip direction, the following equation must be satisfied for slip dislocation to commence :

$$f_s t = \frac{Gd}{2} = \text{constant},$$

where G is the crystal-elastic shear modulus of elasticity for the above specified conditions and d the lattice spacing of the potential slip planes under consideration.

Bragg derived the above equation for the determination of the minimum distance apart of slip planes, $t_{min.}$ when plastic distortion takes place at the conventional monocrystalline yield resistance in shear f_{sy}. If the actual distance t is less than $t_{min} = Gd/2f_{sy}$, then the super-elastic yield resistance in shear f_s must appropriately exceed f_{sy} and approach the value of $G/2$ as t is decreasing towards the value of the lattice spacing d ; the co-ordinate value of the super-elastic shear strain was 0·5. Serious complications are, however, recognized in connection with precipitation, since the simple basic conditions of the ' arrangement ' quoted above are never realized. Furthermore, the shear modulus of elasticity of super-compressed or super-stretched lattices should be considered in such cases.

In Part V no suggestions for the size of precipitate which would limit the super-elastic phase, were made, but the rules for the individual shaping effort of strain energy caused by volume change were presented on the basis of the conventional consideration of quasi-isotropic elasticity. With the latter the fact that precipitates of different orientation develop in one and the same crystal was taken into account, and it was expected that the ideas obtained from the simple quasi-isotropic calculation would be of value, until appropriate intricate investigations have been carried out. It was also emphasized in Part V that the individual shaping effort of such strain energy may be a powerful factor in the one case, but may be entirely suppressed in others by factors such as the mechanics of deposition and surface tension.

Nevertheless I am unable to qualify more than one of my statements made in Part V with regard to Cu precipitation from a matrix of Al-basis ; this I do in a sense opposite to the suggestion of Dr. Gayler. In contradiction to the belief at the time of the preparation of Part V, Bucknell and Geach* have now offered evidence which suggests that the electron microscope can reveal precipitates in aluminium containing 1% of Cu after some ageing even at room temperature. The very first stage is apparently marked by precipitates of compact shape, in agreement with $G_{Cu} > G_{Al}$. The intricate structure and the overall chemical composition of the precipitates is irrelevant in this context, since they must be much richer in Cu than the matrix and must also possess an appropriately increased shear modulus of elasticity of both the monocrystalline type and the quasi-isotropic one. It is also irrelevant whether this compact shape is spherical, or polyhedral because of the influence of the mechanics of deposition and the coherence with the lattice of the matrix. The next development shows the formation of plates by the deposition of copper atoms between primary compact precipitates which are situated near one another in the same lattice plane of the matrix.

This suggests that the compact precipitates develop during the super-elastic phase of precipitation, whilst the formation of the plates commences when the compact pieces reach a size which would make their yield possible. From this phase onward a spreading effort is displayed by the strain energy owing to volume change. The development of a cylindrical shape was postulated in Part V if deposition of progressively deposited copper atoms was the exclusive source of growth during a phase when the precipitate yielded. In practice, precipitation and coagulation operate jointly and lead, apparently by geometrical necessity, to the formation of plates. However, some special nucleation phenomenon may also play a conspicuous rôle if the original compact precipitates possess a lamellar structure. The above reasoning not only accounts for the problem of the Preston-Guinier plates,[1, 2, 6, 7] the existence of which was not explained in Part V, but also suggests, in contradiction to all previous considerations,[1, 2, 6, 7] that the formation of these platelets is associated with the yield of the precipitate and not with the entirely elastic phase of precipitation. This idea would explain why the formation of platelets is co-ordinated with receding hardness.

The experiments discussed above refer to aluminium containing only 1% of Cu. Castaing and Guinier,† using aluminium containing 4% of Cu, have observed with the electron microscope that numerous ' points ' and some ' elongated ' precipitates develop at temperatures between 100° C. and 150° C. This means that compact precipitates developed primarily, and spread subsequently into some shape such as a cylinder or plate. These workers observed points and plates after ageing at 150–200° C. and showed photomicrographs after ageing for 12 hr. at 150° C. and for 3 hr. at 190° C.

F. Keller‡ has recently published an electron-microphotograph of aluminium containing 4·5% of Cu taken after 24-hr. ageing at 250° C. This photograph shows many compact areas of precipitate, and also their ' spreading ' by precipitation and coagulation into plates. Photomicrographs by Dr. Gayler[7] of specimens aged at 130° C. for seven or more days were quoted in Part V. The term ' visible ' was carefully avoided, and the terms ' detectable ' and ' appear ' were used. I feel compelled to adhere to his interpretation of Dr. Gayler's Figs. 20–25 with regard to the most likely shapes of the precipitates.

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* Symposium on Metallurgical Applications of the Electron Microscope. Monograph and Report Series, No. 8, p. 97, 1950, The Institute of Metals.

† *Comptes Rendus*, 1949, vol. 228, p. 2033.

‡ Symposium on Metallurgical Applications of the Electron Microscope. Monograph and Report Series, No. 8, p. 85, 1950, The Institute of Metals.

I hope that the above explanations of super-elasticity will prove to Dr. Gayler that some initial stage of the process of precipitation must be perfectly elastic and cannot be accompanied by any yield.

I recognize, however, the desirability to extend the investigations with the electron microscope to a wider range of temperatures, namely, from sub-zero to 350° C., and to extend ageing times from minutes to weeks. The results of such investigations should clarify the question of cylinder *versus* plate, and other relevant points. It is to be expected that some ideas expressed in my paper may then need revision.

I agree with Dr. Orowan's conclusion that the question of the buckling slip lines could only be decided by a quantitative investigation. The latter appears to be more urgently needed than at first might be considered. All the analytical investigations and speculations of the last 20 years, on dislocation and slip, have been characterized by :

(1) Certain configurations of dislocations, and a mechanism of their propagation being assumed, without any investigation whether or not other possible configurations would be connected with less strain energy

(2) The lack of investigation of why and how twinning should take place under the sole action of an external force of moderate magnitude, although evidence that dislocations of the chosen type could not be produced by an external force, exists.

I cannot agree with Dr. Orowan's qualitative arguments and with the conclusion that buckling of the slip line could not take place. However, I would like to abstain from further qualitative argumentation, and leave the decision to quantitative investigation.

As regards the ' bedding constant ' of the slip lines, I would like to point out that elastic crystal constants refer to strains, the gradient of which is negligible over distances comparable with atomic spacing. If the strain energy associated with buckled slip lines is to be analysed, the strain conditions along, and next to, the slip lines are entirely of opposite character. Using ' atomic ' elasticity, the variation of the ' bedding constant ' with different directions, is found to be much greater than the variation of the conventional elastic crystal constants for the same directions.

Correspondence on the Paper—

THE ACCURATE DETERMINATION OF CARBON IN LOW-CARBON STEELS*

By J. E. Wells

Mr. **Archibald Allison** (Sheffield) wrote : Accuracy of analysis is always of interest to works chemists, and in a works laboratory where the analysis of low-carbon steels, including ingot iron, is a matter of routine and where accuracy is essential, the following method has been adopted for cases when unusual precision is necessary, being somewhat simpler than the method described by the author.

The combustion tubes have a hot length sufficient to take two combustion boats.

Into the combustion tube two blank boats are inserted. The purifying train is the normal one of chromic acid, sulphuric acid, and calcium chloride. A lightweight absorption tube containing soda asbestos and calcium chloride is attached ; the apparatus is coupled up and oxygen passed for 30 min.

The boats are then removed and cooled in a desiccator, and the absorption tube is weighed. Into each boat is weighed a double quantity of the sample, with any approved fuse, sheet lead, red lead, lead chromate, etc., the estimation being made on 10·908 g. contained in the two boats. The apparatus is again coupled up after insertion of the boats and attaching the absorption tube, and after combustion is apparently complete, oxygen is passed for 20 min. and the absorption tube is weighed.

Excellent duplicates are obtained on ingot irons containing as low as 0·01% and 0·020% of carbon, and the results are considered to be forensic. It is a good principle in analysis to operate with as large a sample as possible to obtain greater accuracy, and this appears to be applicable to the present case.

* *Journal of The Iron and Steel Institute*, 1950, vol. 166, Oct., pp. 113–117.

AUTHOR'S REPLY

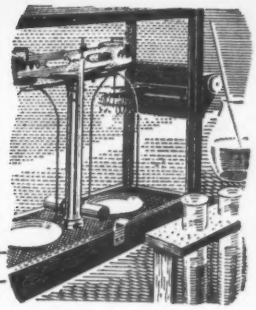
Mr. **J. E. Wells** (The Steel Company of Wales (Lysaght Works), Ltd.) wrote in reply : The apparatus described in my paper is capable of an accuracy of ± 0·0002% of carbon, and was designed for use when carbon determinations of this order of accuracy are required. It can in no way be described as a routine apparatus, but is much simpler than the more elaborate low-pressure methods described by American workers.

Mr. Allinson's method, involving larger sample weights, is, of course, not new. It has been used in many forms by a number of operators. Mr. B. Bagshawe, at the Fourth Chemists Conference, recently described an apparatus in which sample weights of up to 16 g. could be used. This apparatus was capable of giving results accurate to ± 0·001% of carbon and the time per determination was approximately 10 min.

This order of accuracy is insufficient for certain purposes when the samples to be analysed may contain rather less than 0·01% of carbon. It is in such circumstances that the more accurate low-pressure method would be of greatest use.

B. I. S. R. A.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION



An Analysis of Some Roll-Pass Designs for Round Sections

By D. A. Winton, B.Sc.(Eng.), A.M.I.C.E., A.M.I.Mech.E.

SYNOPSIS

Schedules of roll passes for reducing billets to round sections have been analysed and compared. The square–diamond and the oval–square sequences require fewer passes than other sequences to reduce a billet to any particular size of round. An approximate relationship exists between the area per pass, the number of passes preceding it, and the billet area.

The leader pass is found to be nearly elliptical in shape, and curves are given from which leaders may be constructed for any size of round up to 5-in. dia. The design of the finishing pass is also discussed.

Details of the rolls and mills used are given in an appendix.

THIS paper was discussed at a meeting of the Roll Design Conference of the British Iron and Steel Research Association held in 1949. It gives an analysis of some roll-pass designs submitted by four members of the Conference.

For ease of reference the designs, which are shown in the folding insets, are lettered *A*, *B*, *C*, and *D*. Details of the mills and rolls used are given in the Appendix.

PASS SCHEDULES

Several sequences of roll-pass shapes have been devised for the reduction of a billet to a round section, and those included in the designs submitted have been examined in particular for the rate of reduction given by the percentage reduction between two passes, and the shape of the leader and final passes. Table I gives the designers' reasons for the sequences chosen, examples of which are shown in Fig. 1. Two other sequences which are frequently used but were not among the designs examined, are shown in Fig. 2.

Table I shows that the all-squares, and the square–diamond sequences introduce flexibility into the production line should it be necessary to change the rolling schedule to accommodate orders for different sizes of rounds, as well as for squares and hexagons. Design C uses the oval-edging sequence which is said to give a round of good surface finish. This is also the reason for the increasing employment of the round–oval–round sequence. Because of the large angle of bite and the consequent tendency to spreading, the reduction is necessarily less than would be used with other sequences. This fact, together with the better control of the filling of the pass and the convexity of the surfaces of the stock, which prevents wrinkling and trapping of scale, may account for the better surface finish in rounds rolled with the oval-edging or round–oval–round sequences.

Of the actual pass shapes the so-called square passes are not square ; the angle of the groove in the rolls ranges from 90° to 98°. The shape of the diamond for diamond passes also is not constant ; the major angle varies between 100° and 130° according to the reduction and spread desired. For both squares and diamonds the angle is rounded off to prevent the formation of any sharp edges which may be turned over and rolled into the stock and thus give rise to sources of weakness in the finished round.

Rate of Reduction

The designs were analysed to ascertain whether one particular pass sequence gives a greater rate of reduction than others, as this has an important bearing on the final choice of a sequence. The data given in Table II suggested that there was a tendency for the fractional reduction in area per pass to be roughly constant throughout any given schedule. In these circumstances the equation giving the area, A_p, of any pass P is expressed by :

$$A_p = A_o(1 - r)^P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where A_o is the billet area, and r is the fractional reduction in area per pass and is equal to

$$\left[1 - \frac{A_p}{A_{p-1}}\right]$$

Equation (1) can also be expressed in the form

$$\log A_p = \log A_o + P\log(1 - r) \quad \ldots\ldots\ldots\ldots (2)$$

Paper MW/AA/11/49 of the Roll Design Conference of the Mechanical Working Division of the British Iron and Steel Research Association, received 10th May, 1950.

Mr. Winton is Technical Secretary of the Mechanical Working Division of the Association.

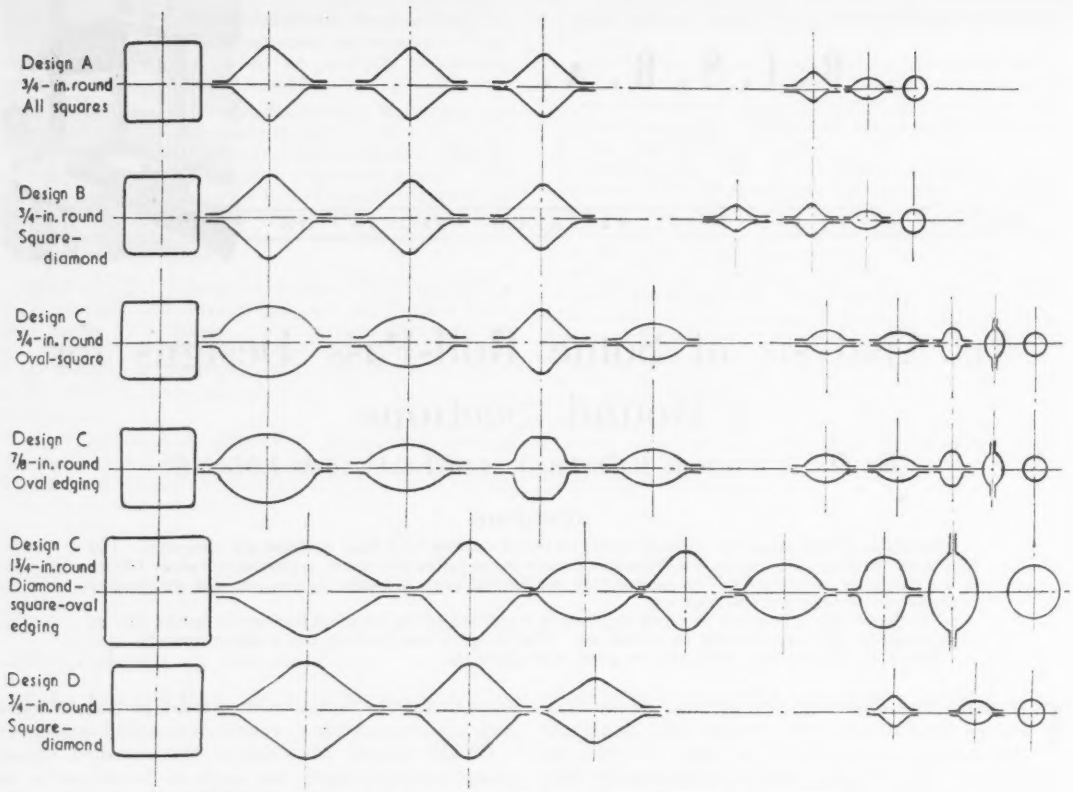


Fig. 1—Examples of the sequences that were analysed and compared

Table I

PASS SEQUENCE

Design	Pass Sequence	Reason for Use of Particular Pass Sequence
A	All-squares	Small orders ; requires fewer changes of rolls
B	Up to 1½-in. dia., square–diamond Up to 3-in. dia., all-squares	Most convenient for various sizes of round rolled
C	¾-in. and 1-in. dia., oval-square ⅞-in. dia., oval-edging	¾-in. and 1-in. dia. rounds are ordinary bars, ⅞-in. is a special coiled bar for drawing and cold heading. Oval-edging is employed, with its easier drafting, to obtain a good quality finish and avoid surface defects
	1-in. dia. and above, diamond–square–oval-edging	For 1-in. dia. and above, the method of reduction is used to obtain a billet with good surface finish at a reasonable rate of production
D	Square–diamond	Flexible design for a number of sizes; facilitates holding up, and gives reasonable percentage reduction in area between passes.

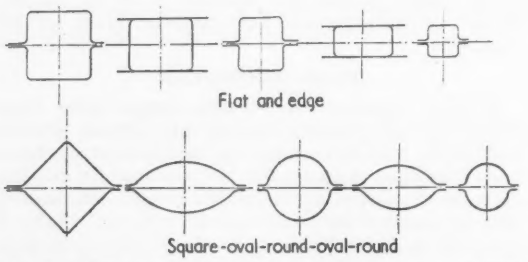
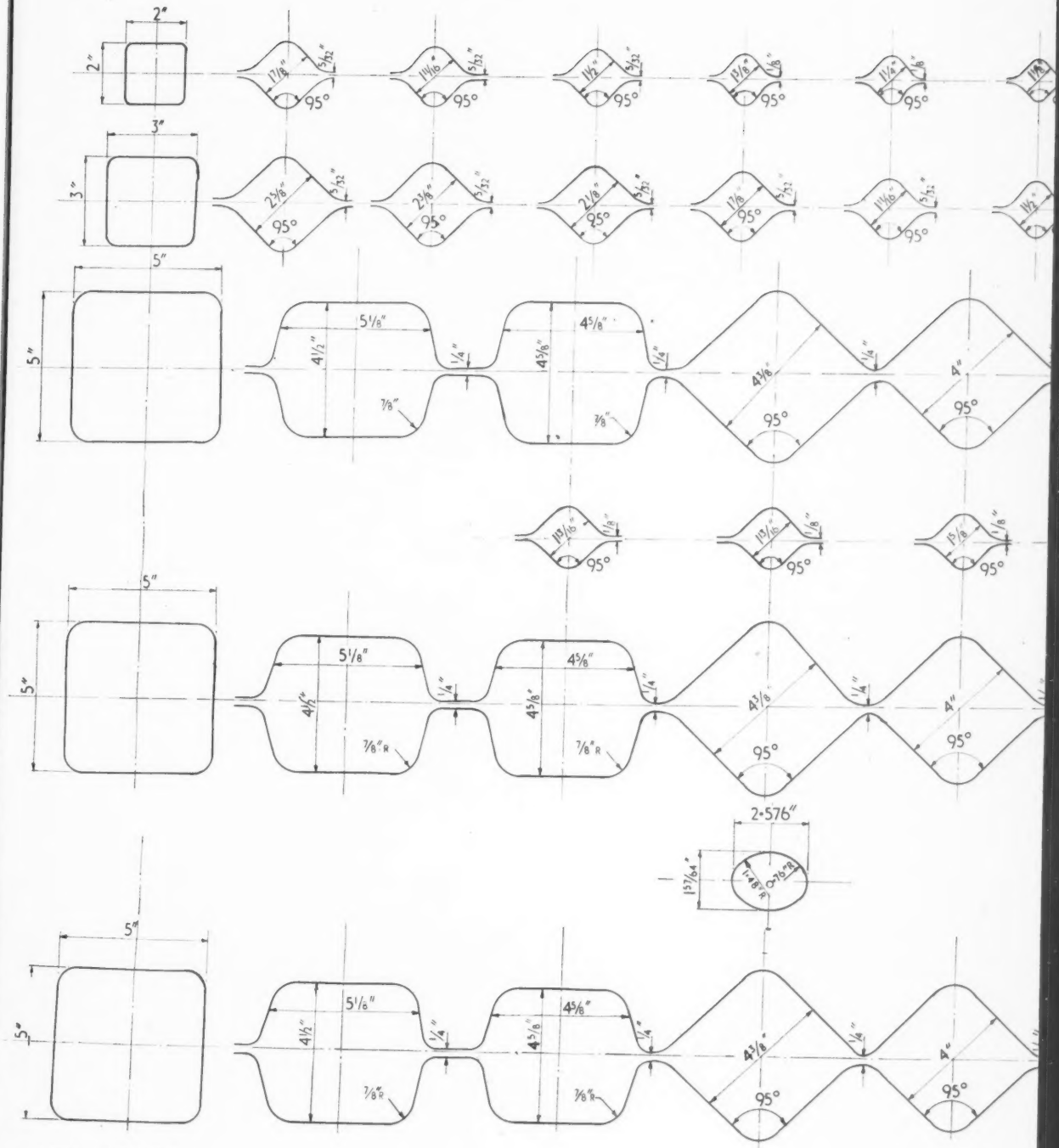


Fig. 2—Two sequences used in practice but not analysed

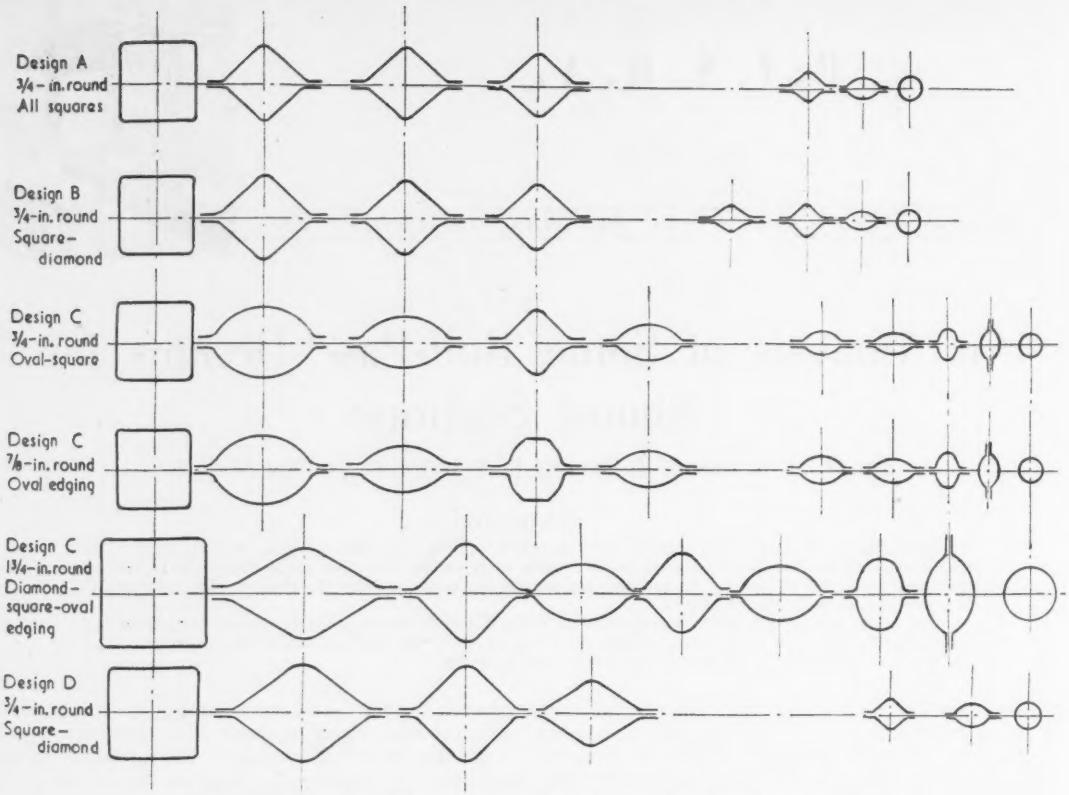
and if r is constant, a straight line of slope $\log(1 - r)$ is obtained by plotting $\log A_p$ against P for a given value of A_o. This is shown in Fig. 3*a*, in which, for ease of plotting, $\log A_p - \log A_o$ is plotted against $P\log(1 - r)$ for representative schedules from each design. In some designs in the finishing passes the points lie away from the straight lines because the reduction per pass is often less in these passes in order to obtain a good shape and surface finish. In other cases the line is stepped where the stock passes through two successive passes of the same area. The slope of the line, however, continues in most cases to remain the same after the step.

Most of the lines of designs *A* and *B* have approximately the same slope, but those of design *D*, except in one instance, are steeper. The lines of design *C*



Scale : $\frac{7}{32}$ full size

[*Winton*
[*To face p. 32*



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C	¾-in. and 1-in. dia., oval-square ⅞-in. dia., oval-edging	¾-in. and 1-in. dia. rounds are ordinary bars, ⅞-in. is a special coiled bar for drawing and cold heading. Oval-edging is employed, with its easier drafting, to obtain a good quality finish and avoid surface defects
	1-in. dia. and above, diamond–square–oval-edging	For 1-in. dia. and above, the method of reduction is used to obtain a billet with good surface finish at a reasonable rate of production
D	Square–diamond	Flexible design for a number of sizes; facilitates holding up, and gives reasonable percentage reduction in area between passes.

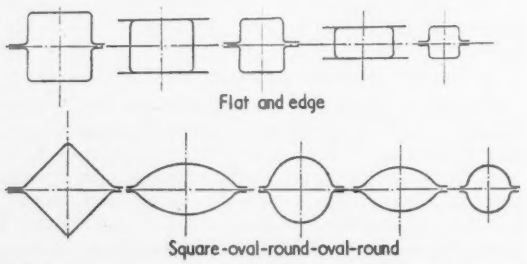

Fig. 2—Two sequences used in practice but not analysed

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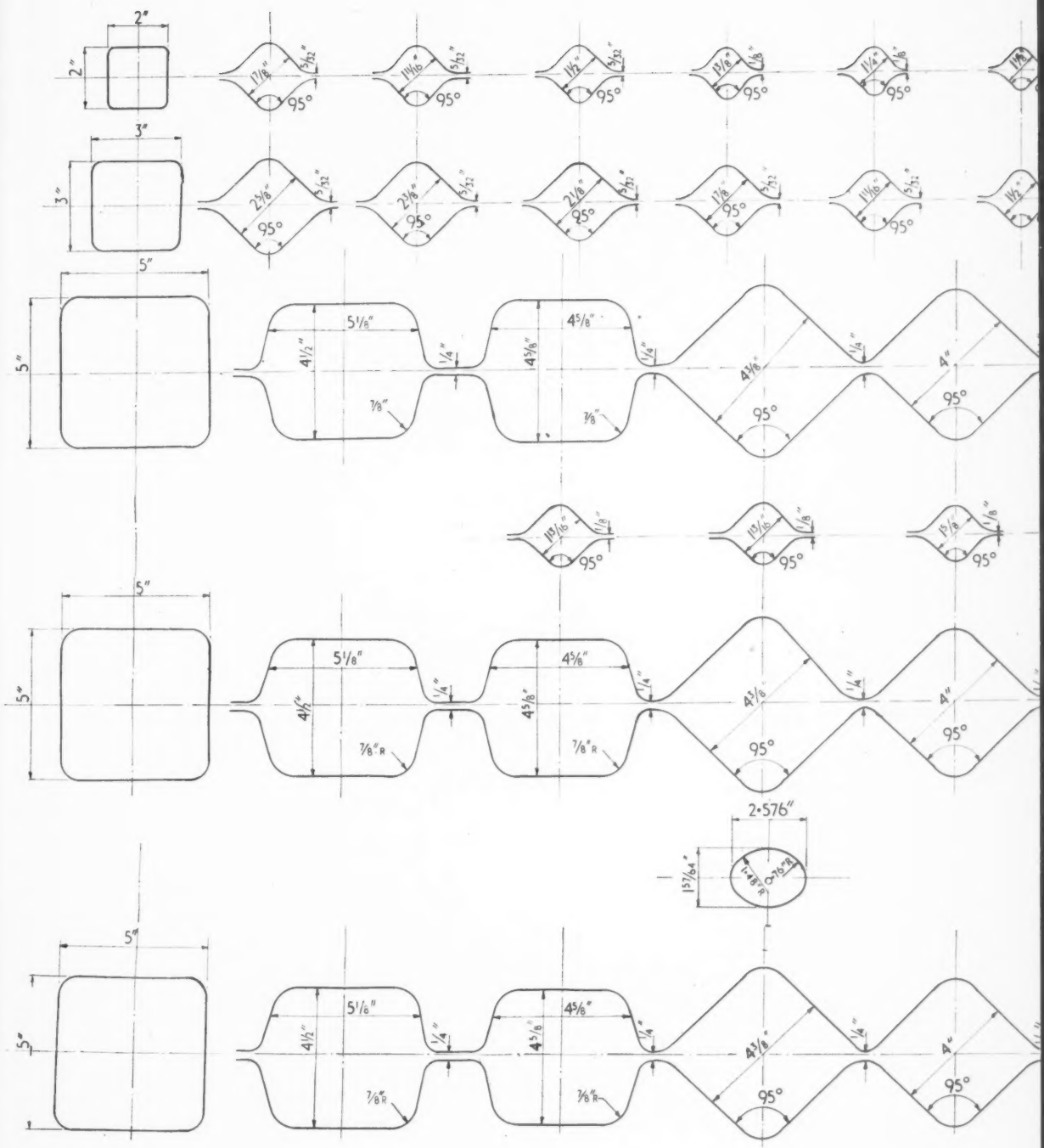
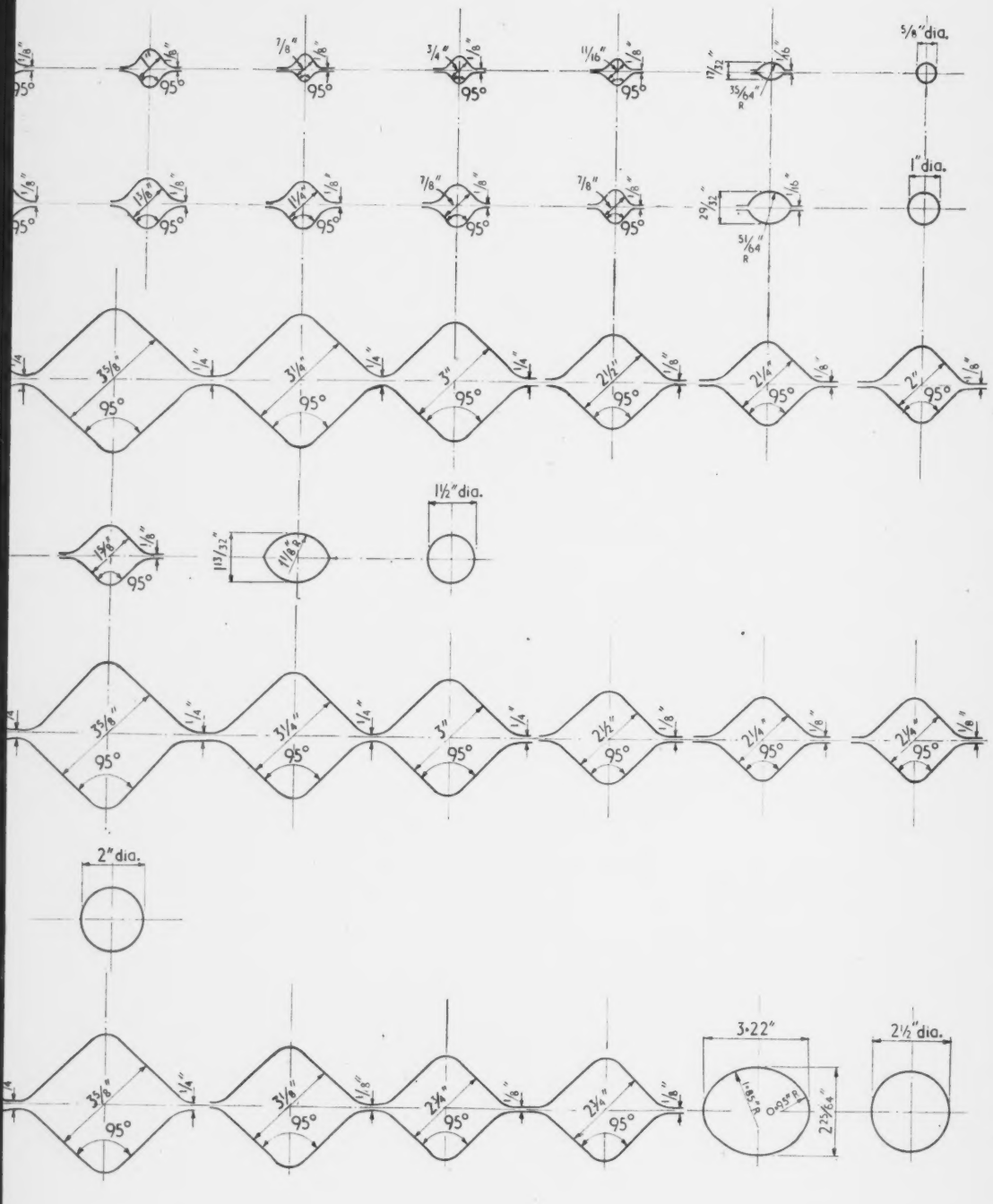
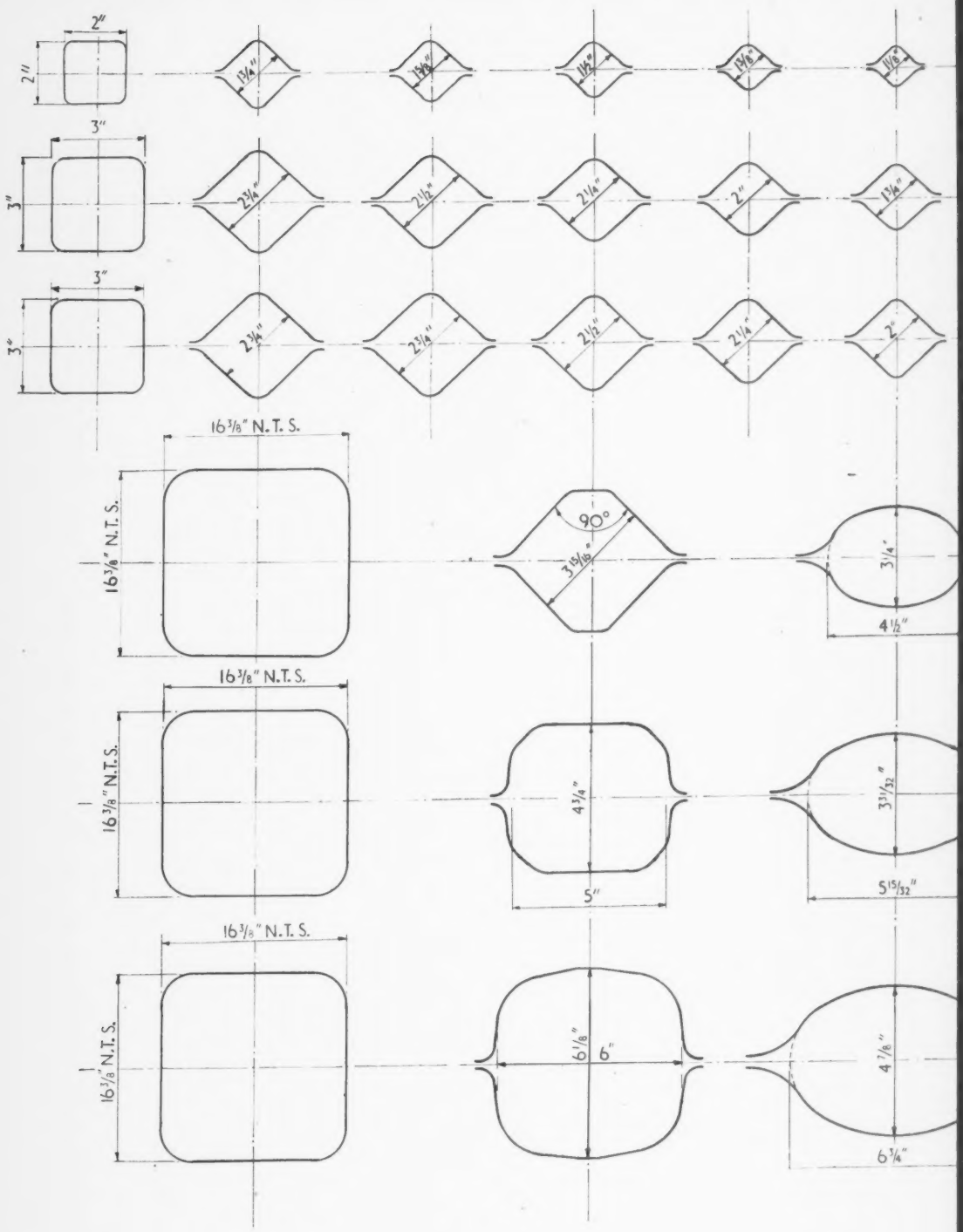


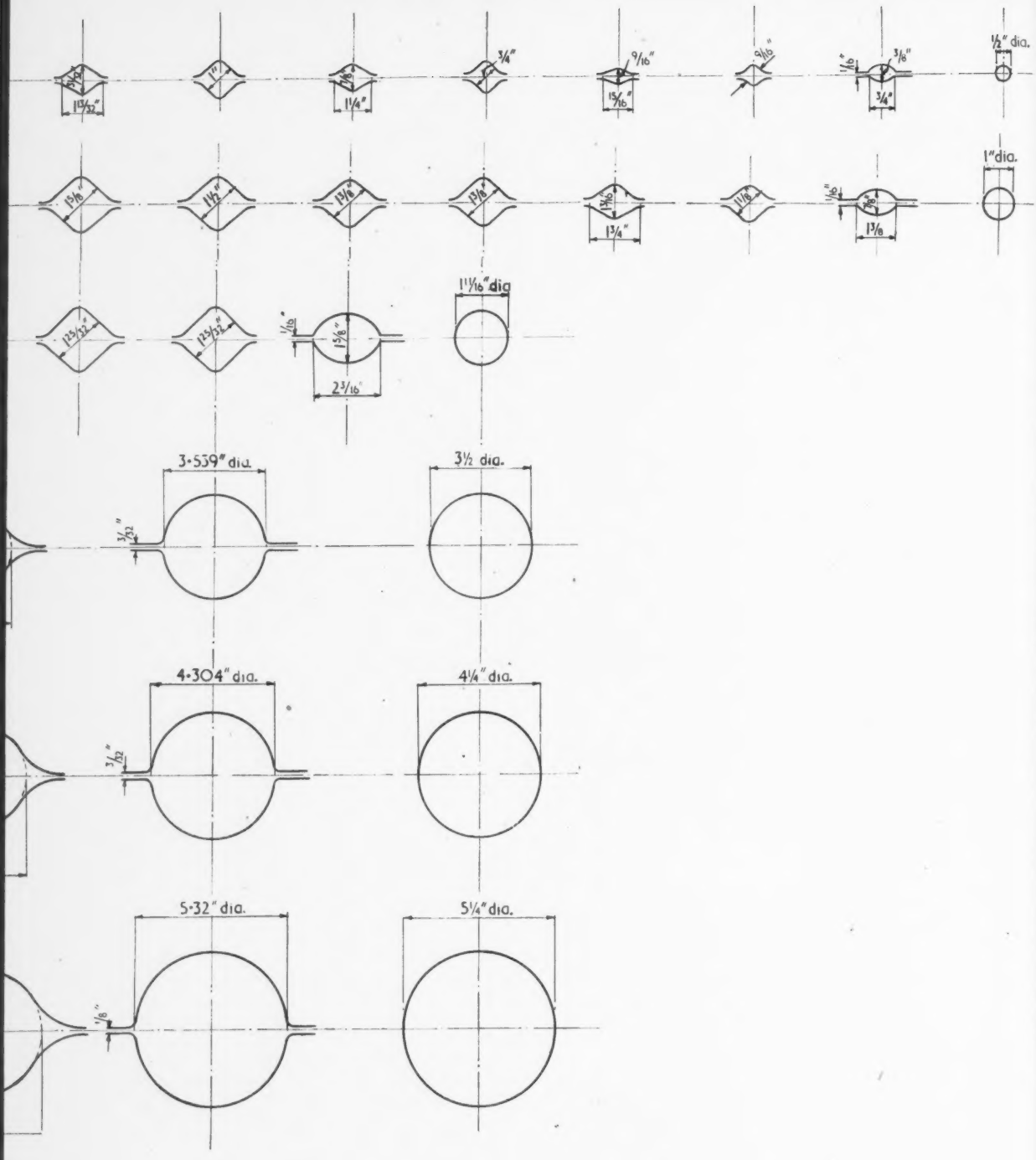
Scale : $\frac{7}{32}$ full size

DESIGN A


5/8" dia.
1" dia.
1½" dia.
2" dia.
2½" dia.
3·22"
95°
3⅝"
3¼"
3"
2½"
2¼"
2"
1¼"
1⅛"
⅞"
¾"
11/16"
17/32"
29/32"
13/32"
¼"
⅛"

DESIGN B


2"
2"
1¾"
1⅝"
1½"
1⅜"
1⅛"
3"
3"
2¾"
2½"
2¼"
2"
1¾"
3"
3"
2¾"
2⅝"
2½"
2¼"
2"
16⅜" N.T.S.
16⅜" N.T.S.
90°
3 15/16"
3¼"
4½"
16⅜" N.T.S.
16⅜" N.T.S.
4¾"
5"
3 31/32"
5 15/32"
16⅜" N.T.S.
16⅜" N.T.S.
6⅛"
6"
4⅞"
6¾"



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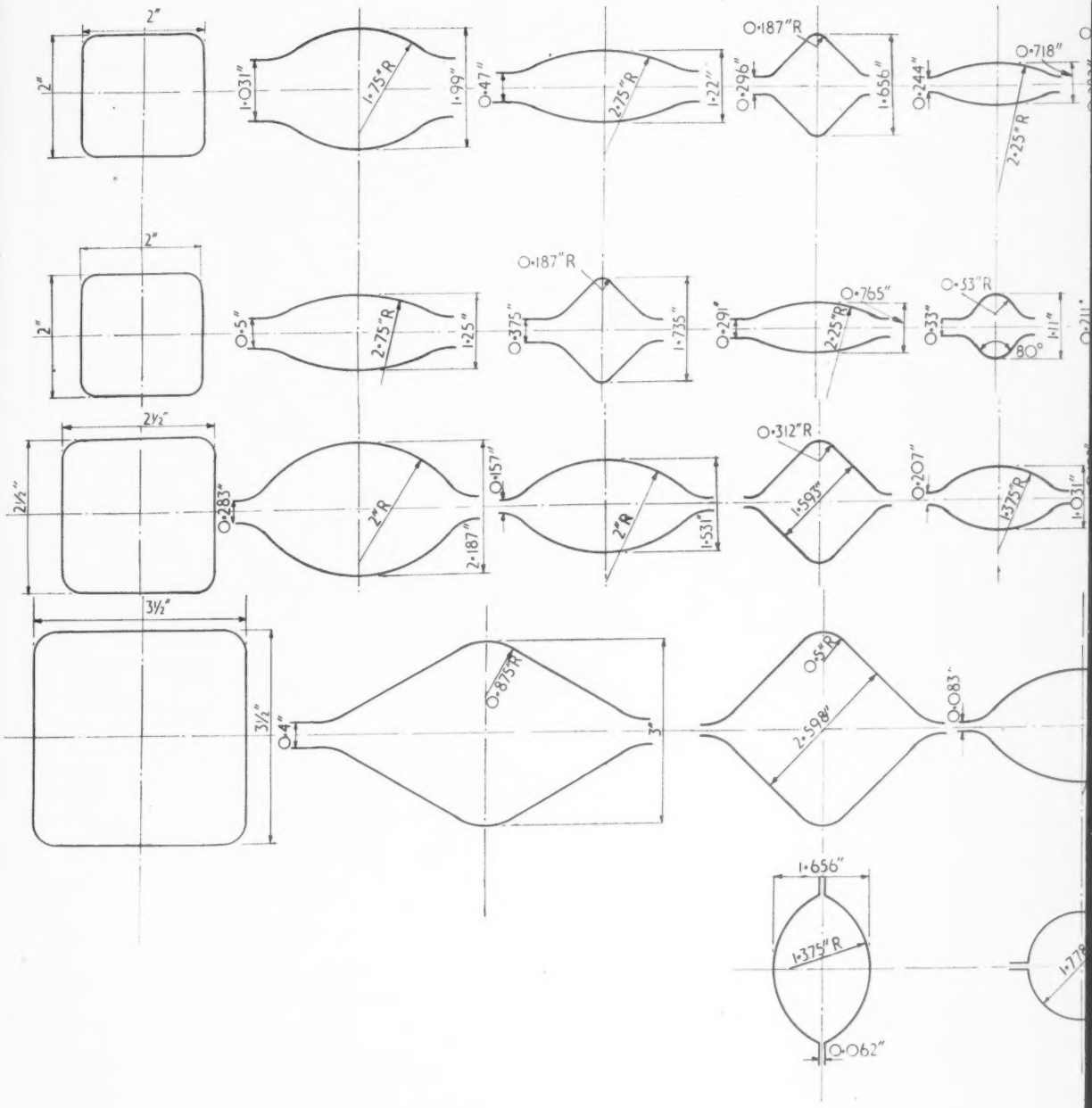
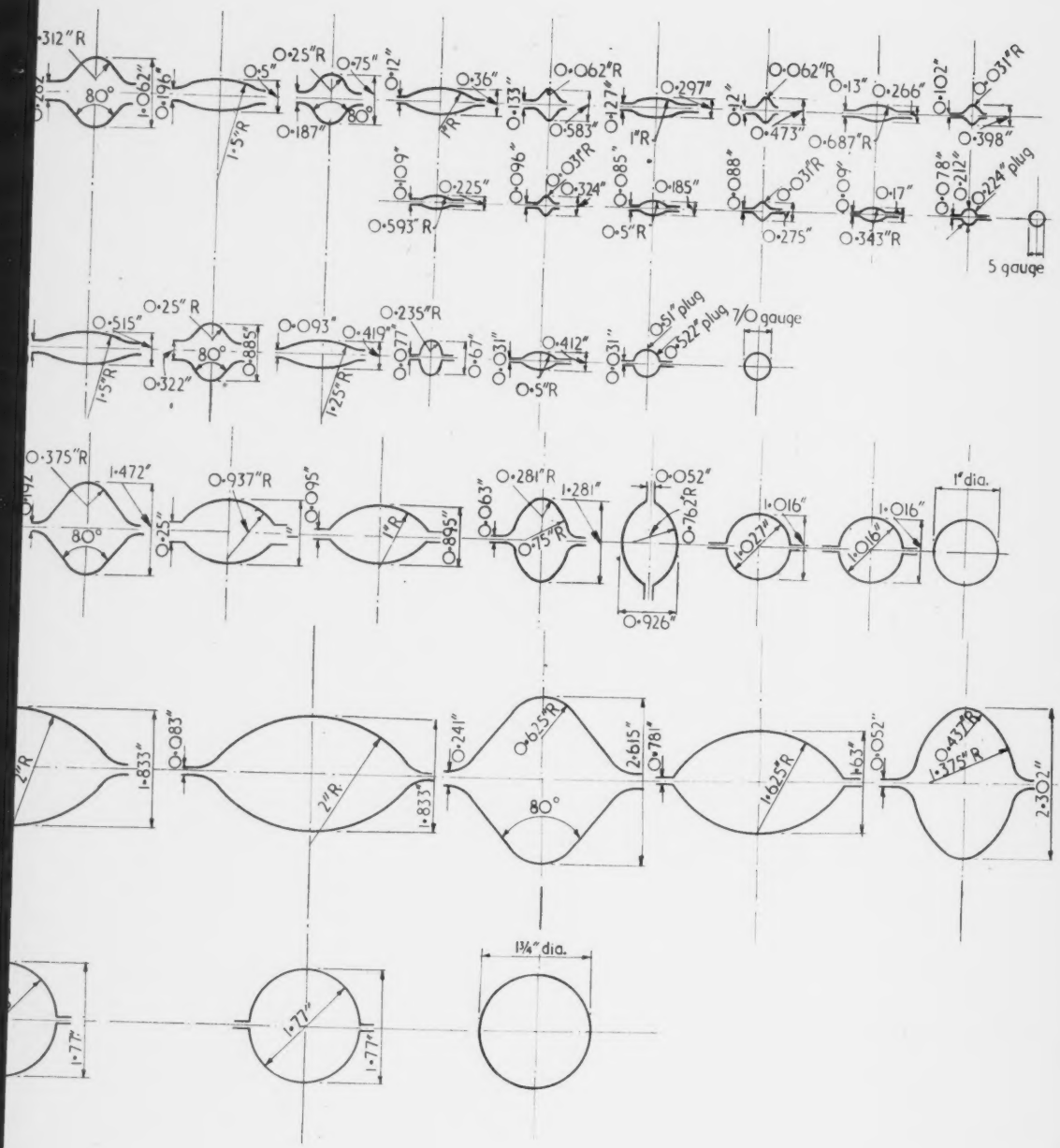
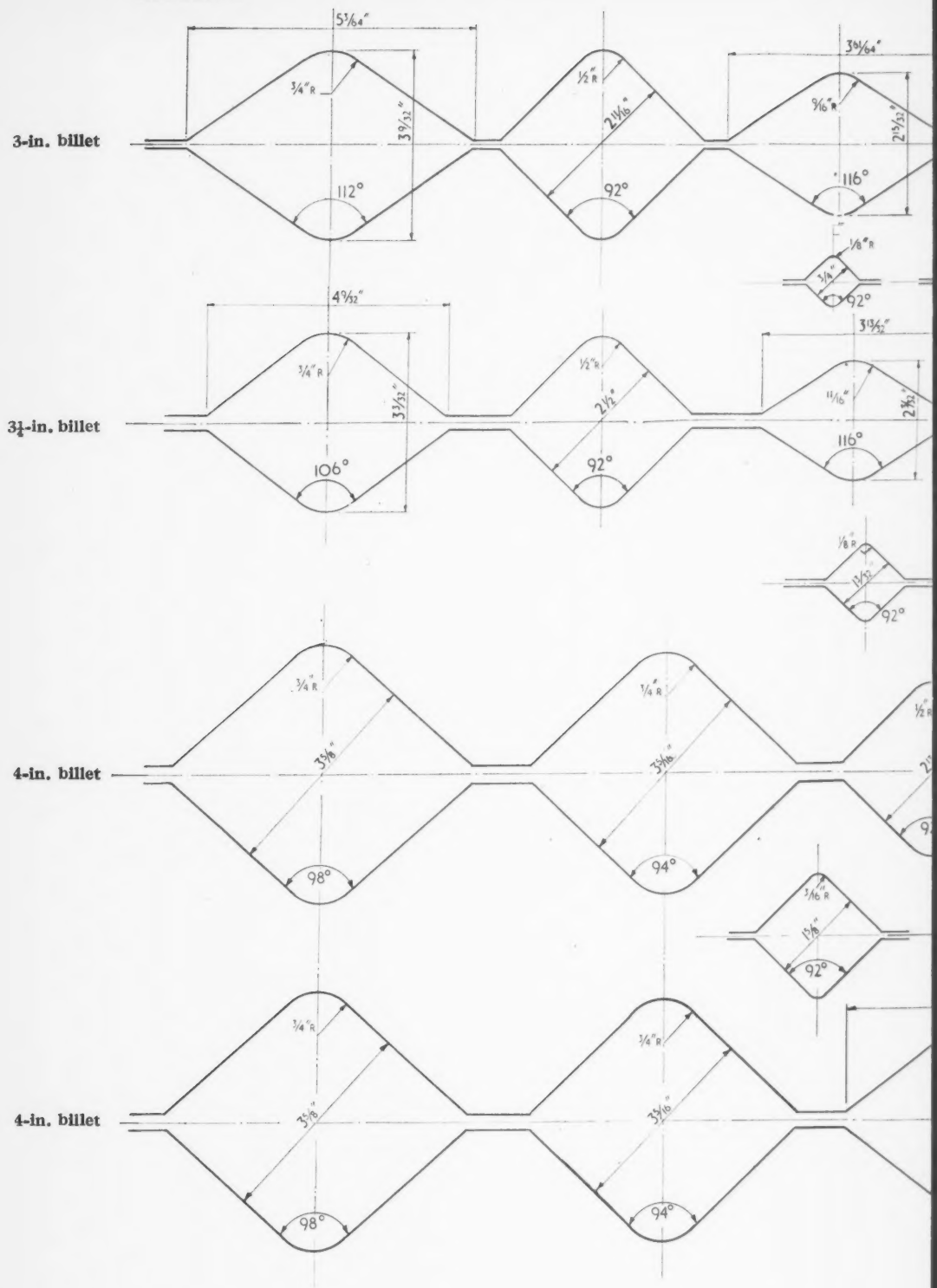


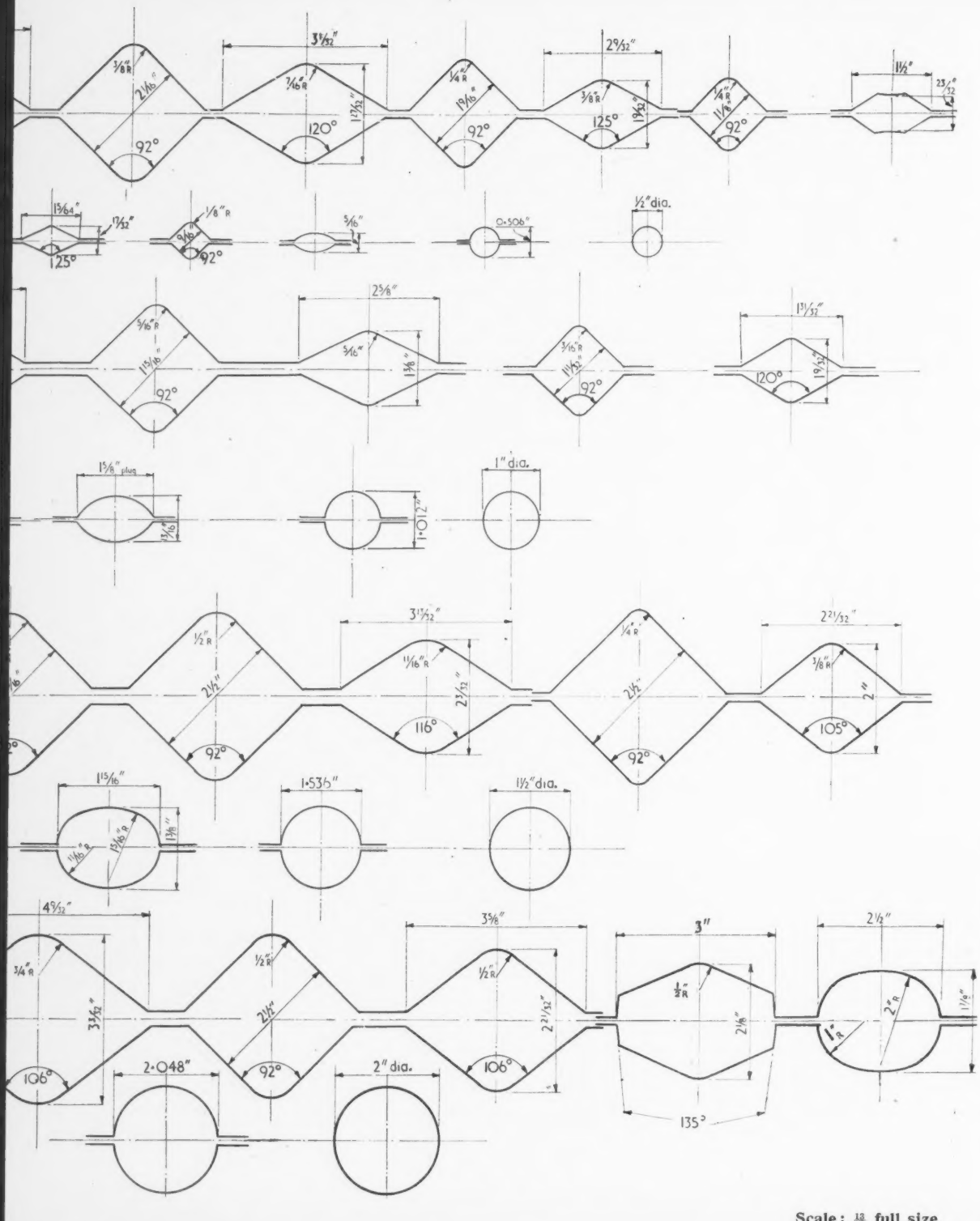
Scale: $\frac{7}{16}$ full size

DESIGN C


·312" R
·282
80°
1·062"
·196"
·5"
·25" R
·75"
·187"
80°
1·5" R
·12"
·36"
1" R
·133"
·583"
·062" R
·127"
1" R
·297"
·12"
·062" R
·473"
·13"
·687" R
·266"
·102"
·031" R
·398"
·109"
·593" R
·225"
·096"
·031" R
·324"
·085"
·5" R
·185"
·088"
·275"
·031" R
·09"
·343" R
·17"
·078"
·212"
·224" plug
5 gauge
·515"
·25" R
80°
·322"
·885"
1·5" R
·093"
·419"
·077"
·235" R
·67"
1·25" R
·031"
·5" R
·412"
·031"
·051" plug
·322" plug
7/0 gauge
·375" R
·192
1·472"
80°
·25"
·937" R
1"
·095"
1" R
·895"
·063"
·281" R
·75" R
1·281"
·052"
·762" R
·926"
1·016"
1·027"
1·016"
1·016"
1" dia.
2" R
1·833"
·083"
2" R
1·833"
·241"
·625" R
80°
2·615"
·781"
1·625" R
·063"
·052"
·437" R
1·375" R
2·302"
1·77"
·77"
1·77"
1¾" dia.

DESIGN D


3-in. billet
5 5/64"
3/4" R
39/32"
112°
1/2" R
2 1/16"
92°
3 1/64"
9/16" R
2 13/32"
116°
1/8" R
3/4"
92°
3-1/4-in. billet
4 9/32"
3/4" R
33/32"
106°
1/2" R
2 1/2"
92°
3 13/32"
11/16" R
2 3/32"
116°
1/8" R
1 1/32"
92°
4-in. billet
3/4" R
3 5/8"
98°
1/4" R
3 5/16"
94°
1/2" R
3/16" R
1 5/8"
92°
4-in. billet
3/4" R
3 5/8"
98°
1/4" R
3 5/16"
94°



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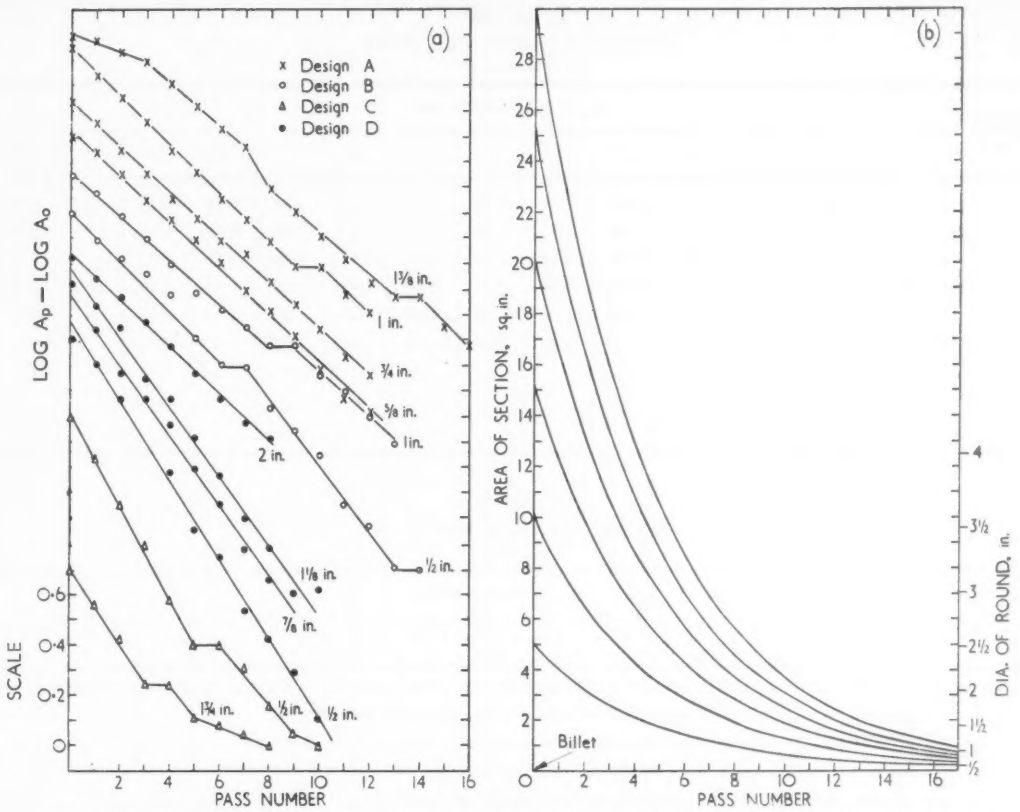

Fig. 3—Relation between area of pass and pass number : (*a*) logarithmic scale; (*b*) linear scale

Table II*a*

DESIGN *A*, AREA PER PASS

(Sq. in.)

Dia. of Round, in.	Pass Number																
	Billet	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
⅛	4·0	3·52	2·86	2·25	1·89	1·57	1·27	1·00	0·83	0·66	0·471	0·375	0·322				
¼	6·25	4·53	3·52	2·86	2·25	1·90	1·56	1·27	1·07	0·87	0·685	0·538	0·460				
⅜	7·56	6·90	5·65	4·52	3·52	2·86	2·25	1·89	1·56	1·27	0·937	0·937	0·937	0·73	0·623		
1	9·0	6·90	5·65	4·52	3·52	2·86	2·25	1·89	1·56	1·23	1·23	0·96	0·812				
1⅛	9·0	6·90	5·65	4·52	3·52	2·86	2·25	1·89	1·89	1·56	1·56	1·31	1·022				
1¼	9·0	6·90	5·65	4·52	3·52	2·86	2·25	1·89	1·89	1·56	1·25						
1⅜	25·0	23·60	21·50	19·30	16·0	13·20	10·60	9·00	6·25	5·08	4·00	3·28	2·64	2·34	2·34	1·75	1·50
1½	25·0	23·60	21·50	19·30	16·0	13·20	10·60	9·00	6·25	5·08	4·00	3·28	3·28	2·8	2·80	2·30	1·77
1⅝	25·0	23·60	21·50	19·30	16·0	13·20	10·60	9·00	6·25	5·08	4·00	3·28	3·28	2·6	2·08		
1¾	25·0	23·60	21·50	19·30	16·0	13·20	10·60	9·00	6·25	5·08	3·75	3·75	3·08	2·40			
1⅞	25·0	23·60	21·50	19·30	16·0	13·20	10·60	9·00	6·25	5·08	5·08	4·45	4·45	3·20	2·77		
2	25·0	23·60	21·50	19·30	16·0	13·20	10·60	9·00	6·25	5·06	5·06	4·00	3·14				
2⅛	25·0	23·60	21·50	19·30	16·0	13·20	9·80	7·58	6·25	5·71	5·71	4·5	3·55				
2¼	25·0	23·60	21·50	19·30	16·0	13·20	9·80	9·80	7·58	6·41	6·41	5·10	4·00				
2⅜	25·0	23·60	21·50	19·30	16·0	13·20	9·80	9·80	7·58	7·10	7·10	5·50	4·44				
2½	25·0	23·60	21·50	19·30	16·0	13·20	9·80	7·10	7·10	6·10	4·90						

Table II*b*

DESIGN *B*, AREA PER PASS

(Sq. in.)

Diameter of Round, in.	Pass Number													
	Billet	1	2	3	4	5	6	7	8	9	10	11	12	13
$\frac{1}{2}$	4·0	3·06	2·65	2·25	1·89	1·27	1·00	1·00	0·69	0·56	0·36	0·30	0·20	0·196
$\frac{3}{4}$	6·25	5·08	3·75	3·06	2·65	2·25	1·89	1·57	1·57	1·27	0·81	0·67	0·46	0·46
$\frac{15}{16}$	6·25	5·08	3·75	3·06	2·65	2·25	1·57	1·57	1·10	0·90	0·77	0·69		
1	9·00	7·58	6·25	5·08	4·00	3·10	2·65	2·25	1·89	1·89	1·44	1·26	1·00	0·78
$1\frac{1}{8}$	9·00	7·58	7·58	6·25	5·08	4·00	3·10	2·65	2·25	2·25	1·90	1·44		
$1\frac{1}{16}$	9·00	7·58	7·58	6·25	5·08	4·00	3·10	3·10	2·50	2·25				
$3\frac{1}{2}$	268	14·44	11·80	9·84										
$4\frac{1}{4}$	268	22·47	17·46	14·55										
$5\frac{1}{4}$	268	32·43	26·33	22·23										

Table II*c*

DESIGN *C*, AREA PER PASS

(Sq. in.)

Dia. of Round, in.	Pass Number																		
	Billet	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
No. 5 Gauge	4·00	4·00	2·75	1·72	1·13	0·80	0·60	0·45	0·30	0·20	0·16	0·12	0·12	0·10	0·085	0·073	0·065	0·057	0·046	0·0353
1/0 ,,	4·00	4·00	2·75	1·72	1·13	0·80	0·60	0·45	0·30	0·19	0·175	0·16	0·12	0·0825						
3/0 ,,	4·00	2·75	1·80	1·25	0·75	0·50	0·50	0·40	0·20	0·14	0·12	0·11	0·11							
7/0 ,,	4·00	2·75	1·80	1·25	0·75	0·50	0·50	0·40	0·26	0·22	0·196									
$\frac{3}{8}$	6·25	5·50	3·60	2·70	1·80	1·30	0·85	0·80	0·75	0·65	0·55	0·50	0·46							
$\frac{7}{8}$	6·25	5·50	4·95	2·70	2·10	1·60	1·15	1·00	1·00	0·85	0·70	0·65	0·62							
1	6·25	5·50	3·30	2·40	1·50	1·50	1·20	1·10	0·90	0·85	0·81									
$1\frac{1}{4}$	7·60	5·00	3·80	2·60	2·60	1·70	1·50	1·50	1·26											
$1\frac{3}{4}$	12·25	9·20	6·50	4·40	4·40	3·20	3·00	2·90	2·46											

are also steeper in the early passes than those of designs *A* and *B*, but their slope decreases in the later passes. Thus design *D*, which employs the square–diamond sequence, has a greater rate of reduction than the all-squares sequences of designs *A* and *B*. The square–diamond schedules of design *B*, however, have a rate of reduction similar to those of design *D*. For the $3\frac{1}{2}$-in., $4\frac{1}{4}$-in., and $5\frac{1}{4}$-in. rounds of design *B* the 268-sq. in. billets are reduced in an ordinary billet mill until their areas are comparatively small ; it is only then that they are rolled in the three shaping passes. These passes are not shown in Figs. 1 and 3*a*.

Design *C* has a rapid rate of reduction in the early passes where either a square–diamond or an oval–square sequence is employed. The reduction is similar to that used in design *D*, but the rate of reduction is very much reduced in those later passes where the oval-edging sequence is used. For the designs examined, therefore, the square–diamond and oval–square sequences have the most rapid, and the oval-edging sequence the slowest, rate of reduction.

A relationship, based on equation (1) and giving the area of the section at any pass in terms of the original billet area,

$$A_p = A_o(0{\cdot}81)^P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

is the best compromise for the all-squares sequences of designs *A* and *B*, and the expression

$$A_p = A_o(0{\cdot}725)^P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

for the square–diamond sequences of design *D*, and the oval–square and the square–diamond sequences of design *C*. For the oval-edging sequence the best expression is

$$A_p = A_o(0{\cdot}90)^P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Thus the average fractional reduction in area per pass is 19% for the all-squares, 27·5% for the square–diamond and oval–squares, and 10·0% for the oval-edging sequence. The reduction into the final round is very nearly the same for all designs and is about 10–15%.

The fractional reduction in area, *r*, between one pass and the next determines the number of passes required, and thus, other things being equal, determines also the time taken to reduce a billet to any required size of round. The larger this ratio, the shorter will be the time required. This is illustrated

Table II*d*

DESIGN *D*, AREA PER PASS

(Sq. in.)

Diameter of Round, in.	Pass Number												
	Billet	1	2	3	4	5	6	7	8	9	10	11	12
$\frac{1}{2}$	9·0	8·08	5·92	4·03	3·04	1·76	1·40	0·85	0·663	0·408	0·319	0·236	0·207
$\frac{9}{16}$	9·0	8·58	6·22	4·68	3·24	2·07	1·72	1·025	0·82	0·482	0·393	0·299	0·262
$\frac{5}{8}$	9·0	8·58	6·22	4·91	3·72	2·65	2·13	1·32	1·00	0·600	0·495	0·364	0·32
$\frac{11}{16}$	9·0	8·58	6·22	4·91	3·72	2·65	2·53	1·63	1·24	0·753	0·592	0·445	0·391
$\frac{3}{4}$	9·0	8·58	6·22	4·47	3·25	1·92	1·48	0·855	0·684	0·528	0·462		
$\frac{13}{16}$	9·0	8·58	6·22	4·47	3·25	1·92	1·56	1·115	0·831	0·627	0·55		
$\frac{7}{8}$	9·0	8·58	6·22	4·47	3·74	2·47	1·80	1·26	0·94	0·716	0·63		
$\frac{15}{16}$	10·6	8·75	6·30	4·90	3·74	2·47	1·90	1·42	1·075	0·83	0·728		
1	10·6	8·90	6·30	4·90	3·74	2·66	2·07	1·55	1·21	0·942	0·828		
$1\frac{1}{16}$	10·6	8·90	6·30	4·90	3·74	2·66	2·17	1·69	1·35	1·055	0·925		
$1\frac{1}{8}$	16·0	13·0	11·25	7·85	5·88	4·13	2·93	1·98	1·55	1·13	1·035		
$1\frac{3}{16}$	16·0	13·0	11·25	7·85	5·88	4·13	3·04	2·2	1·77	1·37	1·20		
$1\frac{1}{4}$	16·0	13·20	11·25	7·98	5·88	4·24	3·04	2·38	1·87	1·44	1·26		
$1\frac{5}{16}$	16·0	13·50	11·70	8·25	6·20	4·75	3·50	2·62	2·06	1·61	1·41		
$1\frac{3}{8}$	16·0	13·50	11·70	8·25	6·20	4·75	3·50	2·78	2·25	1·81	1·54		
$1\frac{7}{16}$	16·0	13·80	11·70	8·55	6·20	4·95	3·99	3·00	2·44	1·92	1·69		
$1\frac{1}{2}$	16·0	13·80	11·70	8·55	6·20	4·95	3·99	3·16	2·64	2·12	1·83		
$1\frac{5}{16}$	16·0	13·00	11·25	7·85	5·88	4·13	2·89	2·31	2·01				
$1\frac{5}{8}$	16·0	13·12	11·25	7·98	5·88	4·24	3·02	2·44	2·13				
$1\frac{11}{16}$	16·0	13·12	11·25	7·98	5·88	4·24	3·28	2·66	2·34				
$1\frac{3}{4}$	16·0	13·50	11·70	8·28	6·22	4·76	3·51	2·86	2·50				
$1\frac{13}{16}$	16·0	13·80	11·70	8·55	6·19	4·94	3·89	3·04	2·67				
$1\frac{7}{8}$	16·0	13·80	11·70	8·55	6·19	4·94	4·10	3·23	2·85				
$1\frac{15}{16}$	16·0	13·80	11·70	8·40	7·75	5·86	4·50	3·49	3·07				
2	16·0	13·80	11·70	9·40	7·75	5·86	4·76	3·76	3·25				

in Fig. 3*a* in which the slopes of the lines are equal to $\log(1 - r)$. Those schedules with larger values of r, *i.e.*, lines with steeper negative slopes, require fewer passes than those with smaller values.

Area and Number of Passes

The area of a pass and the number of passes required will depend on the size and layout of the mill, the temperature of rolling, and other such factors. These, of course, must be taken into consideration when designing the passes, but curves showing the area per pass plotted against the pass number, constructed from equations (1) and (3) and shown in Fig. 3*b*, may give, as a first approximation, the area and number of passes required when designing rolls for a new size of round. These curves are similar to those given on a logarithmic scale in Fig. 3*a*, but are on a linear scale which is more convenient for this purpose and is more easily understood. If a square–diamond or oval–square sequence is employed, the curves should be constructed from equation (4), and from equation (5) for oval-edging sequences. Equations (3), (4), and (5) are empirical and can be used only within the limits of the information given in this paper. They are, however, based on present practice and should give an area/pass curve that will give a satisfactory product.

Figure 3*b* shows, for example, that to roll a 1-in. dia. round from a billet of 20 sq. in., 15 or 16 passes will be necessary. The least number of passes to obtain a given section can also be found ; a $2\frac{1}{2}$-in. dia. round can be produced from a billet of a minimum area of 10 sq. in., four passes being required. Three passes may be sufficient to develop a round from a square billet, but to obtain a satisfactory shape and surface finish at least four passes should be used.

In some of the schedules examined the reduction between two passes is nil. The necessity for the finished section to be delivered on the appropriate side of the mill may account for this, but it may also improve the shape and surface finish of the section before entering the finishing pass, as in design *C* where, for some schedules, the reduction between the preleader and the leader pass is nil and the section runs through vertical rolls at the leader pass.

DESIGN OF THE LEADER AND FINISHING PASSES

The penultimate pass of every sequence is invariably oval in cross-section and is usually referred to as the

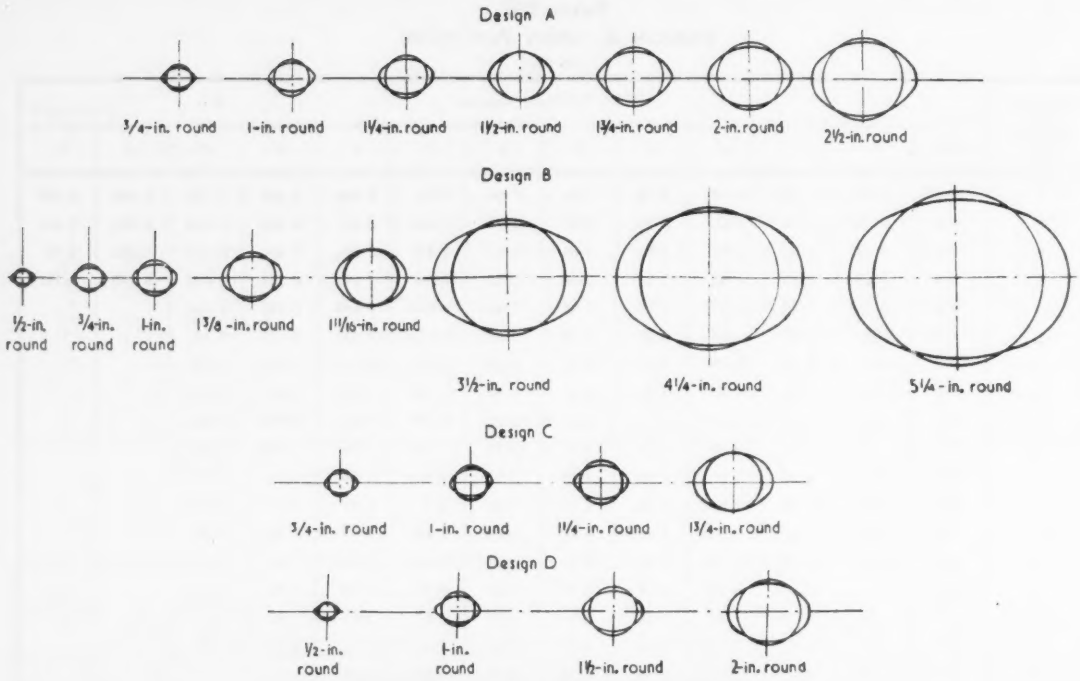

Fig. 4—Comparison of contours of ovals and rounds

leader pass. This pass and the round or finishing pass are most important passes in the rolling schedule, because the design of these ensures that the final section is true to shape and of the correct size.

A representative number of sections, shown in Fig. 4, were taken from each design and a circle was drawn equal to the diameter of the round when hot, with the final oval pass superimposed on it. A sharp oval is used for the smaller rounds and an oval which is blunter or whose shape approaches that of a circle for the large rounds, *i.e.*, for small rounds the ratio of the major axis of the oval to the diameter of the round is greater than that for ovals of large rounds. This agrees with the statement in Table III that single-arc ovals are used generally for rounds up to 2–3 in. dia., and double-arc ovals for larger sizes.

In Fig. 5 values of the major and minor axes of the oval, W and T, respectively, obtained from Table IV, are plotted against the nominal diameter of the round when cold : the points lie on straight

Table III

DESIGN ALLOWANCES FOR LEADERS AND ROUNDS

Design	Oval		Round		
	Type of Oval	Spread Allowance into Round	Contraction Allowance	Spring Allowance	Opening Allowance
A	Single arc up to 2-in. dia. round ; double arc for 2-in. to 2½-in. dia rounds	$\frac{3}{32}$ in.	0·013 in. per 1-in. dia.	$\frac{1}{8}$–$\frac{3}{16}$ in.	None
B	Single arc up to 3-in. dia. round ; double arc above 3-in. dia. round	$\frac{1}{8}$ in.	Approx. 0·02 in. per 1-in. dia.	0·031 in. up to 3-in. dia. round $\frac{3}{32}$ in. for 3½ in. and 4¼ in.; $\frac{1}{8}$ in. for 5¼ in.	Nil up to 3-in. dia. round; 2° above 3-in. dia. round
C	Single arc	From 20% to 40% of draft	0·016 in. per 1-in. dia.	0·031 in.	0·012 in.
D	Single arc	$\frac{3}{32}$ in.	0·012 in. per 1-in. dia.	0·062 in.	0·01 in.

Table IV—DIMENSIONS OF OVAL, in.

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Dia. of Round, Cold, in.	A					B					C					D				
	Dia. (*D*) of Round, Hot, in.	Major Axis, *W*	W/D	Minor Axis, *T*	*T*/*D*	Dia. (*D*) of Round, Hot, in.	*W*	*W*/*D*	*T*	*T*/*D*	Dia. (*D*) of Round, Hot, in.	*W*	*W*/*D*	*T*	*T*/*D*	Dia. (*D*) of Round, Hot, in.	*W*	*W*/*D*	*T*	*T*/*D*
5 Gauge											0·21	0·35	1·65	0·17	0·80					
1/0 ,,											0·32	0·50	1·54	0·25	0·77					
3/0 ,,											0·37	0·60	1·62	0·28	0·74					
7/0 ,,											0·50	0·75	1·50	0·41	0·82					
1/8						0·52	0·75	1·45	0·38	0·73						0·51	0·85	1·68	0·47	0·91
5/16																0·57	0·92	1·62	0·52	0·92
3/8	0·63	0·90	1·42	0·53	0·84											0·63	0·88	1·39	0·56	0·89
11/16																0·70	0·95	1·36	0·62	0·89
3/4	0·76	1·05	1·38	0·66	0·87	0·77	1·06	1·38	0·63	0·82	0·76	1·02	1·33	0·66	0·87	0·76	1·00	1·32	0·67	0·88
7/8	0·89	1·23	1·39	0·78	0·88						0·89	1·17	1·31	0·79	0·88	0·88	1·20	1·37	0·78	0·89
15/16						0·95	1·31	1·38	0·81	0·85						0·94	1·30	1·39	0·84	0·90
1	1·01	1·40	1·38	0·91	0·90	1·02	1·375	1·35	0·88	0·86	1·02	1·30	1·28	0·93	0·91	1·01	1·42	1·40	0·90	0·89
1 1/16																1·08	1·47	1·36	0·96	0·89
1 1/8	1·14	1·55	1·36	1·03	0·90											1·14	1·55	1·36	1·01	0·89
1 3/16																1·19	1·65	1·38	1·07	0·90
1 1/4	1·27	1·70	1·34	1·16	0·91						1·26	1·69	1·34	1·17	0·93	1·27	1·75	1·38	1·13	0·89
1 5/16																1·33	1·78	1·34	1·20	0·90
1 3/8	1·39	1·90	1·37	1·28	0·92	1·41	1·875	1·33	1·31	0·93						1·39	1·81	1·30	1·28	0·92
1 7/16																1·46	1·87	1·28	1·33	0·91
1 1/2	1·52	2·07	1·36	1·41	0·93											1·52	1·94	1·27	1·38	0·91
1 9/16																1·58	2·00	1·27	1·43	0·91
1 5/8	1·65	2·22	1·34	1·52	0·92											1·65	2·06	1·25	1·50	0·91
1 11/16						1·72	2·19	1·27	1·63	0·94						1·71	2·12	1·24	1·57	0·92
1 3/4	1·77	2·38	1·34	1·66	0·93						1·77	2·32	1·31	1·66	0·94	1·77	2·19	1·24	1·63	0·92
1 13/16																1·83	2·25	1·23	1·69	0·92
1 7/8	1·90	2·55	1·34	1·78	0·94											1·90	2·313	1·22	1·75	0·92
1 15/16																1·97	2·40	1·22	1·81	0·92
2	2·03	2·66	1·26	1·89	0·94											2·02	2·50	1·24	1·88	0·93
2 1/8	2·15	2·73	1·27	2·01	0·94															
2 1/4	2·28	2·90	1·27	2·24	0·98															
2 3/8	2·41	3·05	1·27	2·36	0·98															
2 1/2	2·53	3·22	1·27	2·39	0·95															
3 1/2						3·54	4·5	1·27	3·25	0·92										
4 1/2						4·30	5·47	1·27	3·97	0·93										
5 1/2						5·32	6·75	1·27	4·88	0·92										

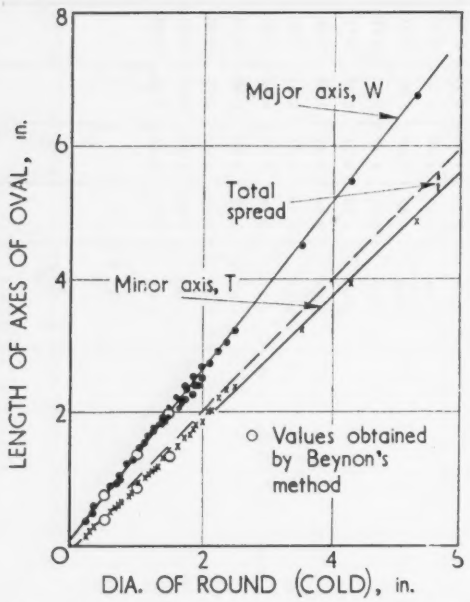

Fig. 5—Relation between axes of the oval and nominal diameter of the round when cold

lines. The expressions for these lines are given, in inches, by the following :

$$W = 1{\cdot}25D + 0{\cdot}10 \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$
$$T = 0{\cdot}96D - 0{\cdot}08 \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where D is the diameter in inches of the round when cold.

Trinks[1] gives details of formulæ used in Germany for calculating the dimensions of the oval. These formulæ give ovals of which the major axes are shorter and the minor axes longer than those obtained from either Beynon's method[2] or from equations (6) and (7). Beynon's method is used for obtaining the dimensions of the axes of the final oval for rounds between $\frac{1}{2}$ in. and $1\frac{1}{2}$ in. dia. Values given by this method (*see* Fig. 5) agree well with the actual values used. It would appear, therefore, that Beynon's method could be extrapolated for larger rounds.

The area of each oval, as given in Table II, was plotted against the diameter of the appropriate round in Fig. 6*a* ; the points lie on a smooth curve. Also shown are values of the area of the oval, assuming it to be an ellipse, calculated from the relationship :

$$\text{area} = \tfrac{\pi}{4}WT, \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where W and T are obtained from the curves given in Fig. 5. These calculated values lie close to the mean line through the actual values.

The area of the oval for a given round obtained from the curve in Fig. 6*a*, or calculated from the formula given in equation (8), should agree with that obtained from the curves in Fig. 3*b*. Thus the area for the oval of a $1\frac{1}{2}$-in. dia. round from Fig. 6*a* is 2·10 sq. in. The area given by Fig. 3*b* varies slightly, depending on the original billet area chosen. It is obtained in the following way :

If the billet area is 25·0 sq. in., 13 passes will be required to reduce it to a $1\frac{1}{2}$-in. dia. round. The area of the 12th pass, *i.e.*, the oval pass, is seen to be 2·00 sq. in. If a billet of 15·0 sq. in. is used 10 passes will be required to produce the round and the area of the 9th pass in this case is 2·30 sq. in.

If other sequences based on equations (4) or (5) are used, the number of passes required will be different but there will be little change in the area of the oval.

Also shown in Fig. 6*a* is the area of the preleader pass for rounds of different diameters. The points lie on a fairly smooth curve, irrespective of the shape of the pass. Most of the preleader passes are square, but some of those in the schedules of design *C* are oval, and those of the $3\frac{1}{2}$-in., $4\frac{1}{4}$-in., and $5\frac{1}{4}$-in. rounds of design *B* are gothic in shape. Tafel[3] suggests that for small rounds the side of the square is equal to the diameter of the round. To check this the curve was re-plotted in Fig. 6*b* against the square of the diameter of the round. The points lie close to a straight line not only for the smaller rounds, but, as would be expected from Fig. 6*a*, for all sizes of rounds. The equation for this line is area $= 1{\cdot}20D^2$, which means that the side of the pass, if square, is approximately equal to $1{\cdot}10D$.

The area of the oval was also plotted on this basis and a straight line can be drawn through the points. The equation of this line is area $= 0{\cdot}960D^2$. Values obtained with this expression agree with those obtained previously, in which the oval is assumed to be elliptical and in which the area is given by $\pi 4/WT$. From equations (6) and (7) the area $\pi WT/4$ is equal to :

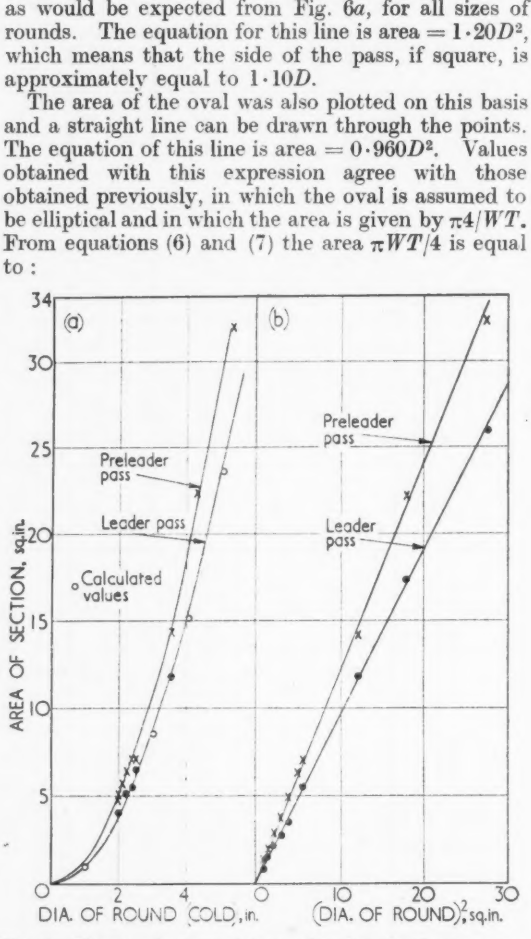

Fig. 6—Changes in area of the oval and preleader passes: (*a*) with diameter of the round; (*b*) with the square of the diameter of the round. In (*a*) all points below 2 in. dia. have been omitted from the curve for clarity

$$\frac{\pi}{4}(1{\cdot}25D + 0{\cdot}1)\,(0{\cdot}96D - 0{\cdot}08)$$

$$= \frac{\pi}{4}(1{\cdot}20D^2 - 0{\cdot}1D + 0{\cdot}096D - 0{\cdot}008)$$

$$\simeq \frac{\pi}{4}(1{\cdot}20D^2) = 0{\cdot}95D^2$$

The amount of the spread can be found from Fig. 5 for any size of round, and values for the total spread from oval into round agree fairly well with those given in Tables III and IV. Values obtained from Ekelund's formula[4] which is frequently employed for estimating spread were compared with those used in practice, and the formula was found to give values similar to those used in the designs analysed. The values are as follows :

Dia. of Round, in.	Total Spread, in.	
	Ekelund's Formula	From Fig. 5
½	0·100	0·08
2	0·20	0·15
4	0·25	0·25

Values of the roll radius and the mean height at entry and exit similar to those used in the designs were taken when calculating spread by Ekelund's formula. The dimensions relate to the shape of the pass, but those of the actual stock may be different. Although the actual spread increases with increase in the diameter of the round, the spread when expressed as a percentage of the diameter of the round, decreases.

Values of W/D and T/D, where D is the diameter of the round when hot, are given in Table IV and plotted in Fig. 7 against the nominal diameter of the round when cold. These curves illustrate the points mentioned earlier about the shape of the oval and the ratio of the lengths of the major and minor axes (p. 36). D was taken as the diameter of the round when hot for a true comparison between the actual pass shapes.

A small section has little torsional strength and it is for this reason that the ratio W/T increases as the diameter of the round decreases. This, however,

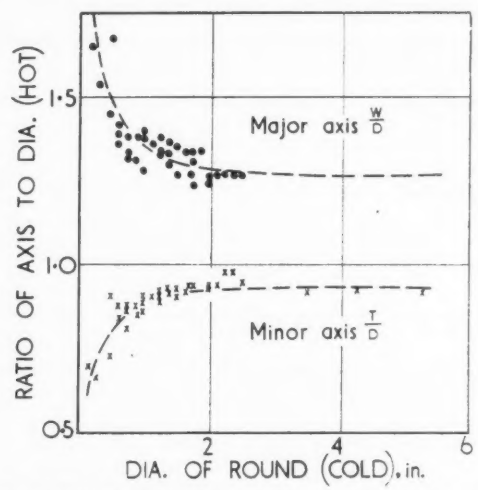

Fig. 7—Relation between the ratio of the axis to the diameter when hot and the diameter of the round when cold

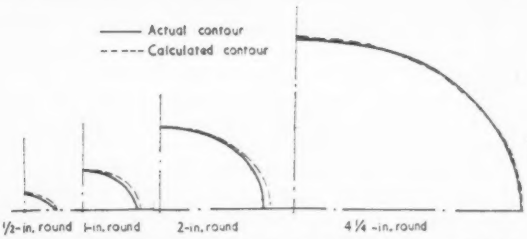

Fig. 8—Comparison of contours of the ovals used in the designs with those of ovals constructed from values of W and T obtained from Fig. 5

necessitates a larger draft in the last pass, with consequently greater wear of the rolls than would be expected if the major and minor axes were nearly equal in length.

To check the contour of an oval of elliptical shape with the ovals used in the designs, ovals for ½-in., 1-in., 2-in., and 4¼-in. dia. rounds were constructed from values of W and T obtained from Fig. 5 and are shown in Fig. 8. These shapes are very similar to those used in practice (*see* Fig. 4), examples of which are also shown in Fig. 8. Thus a satisfactory pass design should be obtained if the oval is elliptical.

Figure 9 gives suggested shapes for leader passes of elliptical shape for rounds between ½-in. and 5-in. dia. Passes for rounds of intermediate sizes not given in the figure can be obtained by interpolation.

In all designs an allowance is made in the round for the contraction of the section after rolling. Thus the size of the groove in the roll is greater than the finished round. The contraction allowance varies from about 0·012–0·02 in./in. of dia. (*see* Table III), which is consistent with a coefficient of linear expansion of $0{\cdot}125 \times 10^{-4}$° C. and a drop in temperature after rolling of about 1000° C.

CONCLUSIONS

Only a few designs have been available for examination and it is upon these that the conclusions have been based. The designs analysed, however, represent a fair sample of current practice in roll-pass design and are claimed to produce satisfactory rounds. Nevertheless, there may be other designs not examined which may produce rounds more true to shape and with a better surface finish, or which may perform the same reduction in fewer passes.

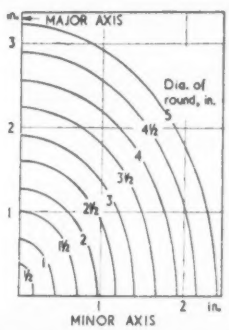

Fig. 9—Suggested ovals for certain sizes of round

From the present analysis the square–diamond and oval–square sequences require fewer passes than other sequences to reduce a billet to any particular size of round, and the fractional reduction in area per pass is approximately constant for a given sequence and throughout any schedule.

The larger the fractional reduction of area per pass the more efficient is the sequence from the point of view of the rate of production; this of course is conditional on the shape and surface of the rolled stock remaining satisfactory.

The shape of the leader pass is very nearly elliptical and is longer and narrower as the size of the round diminishes. Values of the area of the leader calculated on the assumption that it is an ellipse, or that the fractional reduction in area is constant throughout a schedule of passes, agree closely with the actual values used. The spread from the leader pass into the final pass, expressed linearly, increases with the diameter of the round and can be found from Ekelund's formula. The spread expressed as a percentage of the diameter of the round decreases with increase in diameter.

Acknowledgments

The author wishes to thank the members of the Roll Design Conference for their helpful advice and suggestions and especially Mr. G. Bedford, Mr. F. R. Harris, Mr. W. Jennings, Mr. B. Robinson, who prepared the designs, and Mr. W. C. F. Hessenberg, Head of the Mechanical Working Division of the British Iron and Steel Research Association.

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APPENDIX

Details of Mills and Rolls

Details of the mills and rolls used by the designers are given in Tables V*a* and *b*. Although there are insufficient designs to relate any of the details to a particular pass design, and each separate mill is used to roll sections other than rounds, the information may be of interest.

Several different sizes and types of mill are used, ranging from a two-high three-stand reversing 32-in. mill to a five-stand Morgan continuous 10-in. mill. Either steam or electricity is used to provide the motive power.

The Morgan mill is the only one in which twist guides are used ; in all other mills entry into a pass is carried out by hand. In all, however, guides are used for the final pass.

Steel and cast iron rolls are used, but there is insufficient data to indicate which type will give a

Table V*a*

DETAILS OF MILLS

Design	Type	Nominal Size of Rolls, in.	Motive Power	Range of Sizes of Rounds, in.	Cooling Bed	Shears	Guides		Repeaters
							Twist	Final	
A (*a*)	Five-Stand 3-High	8	Steam	$\frac{5}{8}$–$1\frac{1}{4}$	90-ft. long mechanical cooling bed	At rolls and after cooling	None	Yes	Hand
(*b*)	Five-Stand 3-High	12	Steam	$1\frac{1}{8}$–$2\frac{1}{2}$	50-ft. long cooling bed, flats on edge	Hot saw before cooling bed	None	Yes	Hand
B (*a*)	Single Train Roughing 3-High Strand 2-High Oval 2-High Round 2-High	10	Electric	$\frac{1}{2}$–$\frac{31}{32}$	60-ft. long non-mechanical, inclined	At rolls before the hot bed	None	Yes	Hand
(*b*)	Single Train Roughing 2-High Oval 2-High Round 2-High	12	Electric	1–$1\frac{31}{32}$	60-ft. long non-mechanical, inclined	At rolls before the hot bed	None	Yes	Hand
(*c*)	2-High reversing	Cogging 36 Roughing 30 Finishing 28	Steam	$3\frac{1}{2}$–6	140-ft. long cooling bed and rail bank	At rolls between cogging and roughing	None	Yes	Hand
C (*a*)	Morgan Continuous Bar and Strip Mill	$16\frac{1}{2}$–$11\frac{1}{2}$	Electric	$\frac{5}{8}$–$1\frac{31}{32}$	Cooling bed saw tooth carry-over type	Snap shears at rolls; rotary disc shears at hot bed	Yes	Yes	Mechanical
(*b*)	Morgan Continuous Bar and Strip Mill	$16\frac{5}{16}$–$11\frac{1}{2}$	Electric	$1\frac{1}{16}$–$1\frac{31}{32}$	Cooling bed saw tooth carry-over type	Snap shears at rolls; rotary disc shears at hot bed	Yes	Yes	Mechanical
D (*a*)	Belgian Type	10	Electric	$\frac{1}{2}$–$1\frac{1}{8}$	90-ft. long cooling bed	Between roughing and finishing stands. No shears at hot bed	None	Yes	None
(*b*)	Belgian Type	12	Electric	$\frac{7}{8}$–$2\frac{3}{8}$	110-ft. long plain sloping rail-type cooling plate	Between roughing and finishing stands. No shears at hot bed	None	Yes	None

Table V*b*

DETAILS OF ROLLS

Design	Quality	Length, in.	Diameter, in.	Life, tons	Rate of Rolling, tons/hr.	Descaling	*L*/*D*	Amount Cut Off at Each Dressing, in.	Amount Rolled Between Dressings tons	Total Reduction in Dia. During Life, in.	Temp. of Rolling, ° C.	
											First Pass	Last Pass
A (*a*)	Cogging—steel	63	13$\frac{3}{4}$				4·6			2	1150	950
	1st stand—steel	38$\frac{1}{2}$	9	No Records	5 for $\frac{3}{4}$-in. dia. rounds	Plentiful supply of water	4·3	No Records	No Records	1$\frac{5}{8}$		
	2nd stand—steel	25	9				2·8			1$\frac{1}{8}$		
	Oval—chilled iron	8	9				0·9			1		
	Round—chilled iron	8	9				0·9			1		
(*b*)	Cogging—steel	66	18$\frac{1}{2}$				3·6			2$\frac{1}{4}$	1150	950
	1st stand—steel	37	13$\frac{1}{2}$	No Records	6$\frac{1}{2}$ for 1$\frac{1}{2}$-in. dia. rounds	Plentiful supply of water	2·8	No Records	No Records	1$\frac{13}{16}$		
	2nd stand—steel	37	13$\frac{1}{2}$				2·8			1$\frac{13}{16}$		
	Oval—chilled iron	12	13				0·9			1$\frac{1}{4}$		
	Round—chilled iron	12	13				0·9			1$\frac{1}{4}$		
B (*a*)	Roughing—grain	36	10$\frac{1}{2}$	3240 for $\frac{1}{2}$-in. dia.. 6500 for $\frac{3}{4}$-in. dia. rds.	1·81 for $\frac{1}{2}$-in. dia. rds. 3·12 for $\frac{3}{4}$-in. dia. rds.	Copious water	3·5	$\frac{1}{4}$	324	1	1200	900
	Strand—chilled iron	24	10$\frac{1}{2}$				2·4	$\frac{1}{4}$		$\frac{3}{8}$		
	Oval—chilled iron	12	10				1·2	$\frac{1}{16}$		$\frac{1}{8}$		
	Round—chilled iron	12	10				1·2	$\frac{1}{16}$		$\frac{1}{8}$		
(*b*)	Roughing—grain	48	12$\frac{5}{8}$	19,500 for 1-in. dia. rds.	3·75 for 1-in. dia. rds.	Copious water	3·8	$\frac{1}{4}$	1000	1$\frac{1}{4}$	1200	900
	Oval—chilled iron	18	12$\frac{1}{2}$				1·45	$\frac{1}{16}$		1$\frac{1}{4}$		
	Finishing—chilled iron	18	12$\frac{1}{2}$				1·45	$\frac{1}{16}$		1$\frac{1}{4}$		
(*c*)	Special alloy grain rolls	81	36	35,000	36 to 40	Copious water	2·25	$\frac{1}{8}$–$\frac{1}{4}$	1500	3$\frac{1}{2}$	1200	900
		87	30				2·9					
		69	28				2·5					
C (*a*)	Straight carbon chill or indefinite chill	31$\frac{1}{2}$	16$\frac{7}{16}$	83,000	42 for $\frac{3}{4}$-in., 43 for $\frac{7}{8}$-in., 45 for 1-in. dia. rds.	High pressure water	1·9	$\frac{1}{16}$	4900	1$\frac{1}{4}$	1250	940
		31$\frac{1}{2}$	14$\frac{15}{16}$	102,900			2·2	$\frac{1}{16}$	4900	1$\frac{1}{4}$		
		24	13	102,900			1·8	$\frac{1}{16}$	4900	1$\frac{1}{4}$		
		16	11$\frac{1}{2}$	49,300			1·4	$\frac{1}{16}$	2900	1		
		16	11$\frac{1}{2}$	20,111			1·4	$\frac{1}{16}$	1183	1		
(*b*)	Straight carbon chill or indefinite chill	31$\frac{1}{2}$	16$\frac{7}{16}$	66,850	44 for 1$\frac{1}{4}$-in., 40 for 1$\frac{3}{4}$-in. dia. rounds	High pressure water	1·9	$\frac{1}{16}$	2670	1$\frac{1}{4}$	1250	940
		31$\frac{1}{2}$	14$\frac{27}{32}$	66,750			2·2	$\frac{1}{16}$	2670	1$\frac{1}{4}$		
		24	13	56,100			1·8	$\frac{1}{16}$	2670	1$\frac{1}{4}$		
		16	11$\frac{1}{2}$	29,563			1·4	$\frac{1}{16}$	1739	1		
		16	11$\frac{1}{2}$	18,275			1·4	$\frac{1}{16}$	1075	1		
D (*a*)	Roughing—grain	54	18$\frac{3}{4}$	15,000	3 for $\frac{1}{2}$-in. dia. rounds	Copious water	2·9	$\frac{1}{2}$	4000	1$\frac{1}{4}$	1250	990
	Small roughing—alloy iron	30	10$\frac{3}{4}$	12,000			2·8	$\frac{1}{16}$	3000	$\frac{3}{4}$		
	Intermediate chilled iron	30	10$\frac{3}{4}$	12,000			2·8	$\frac{1}{16}$	2000	$\frac{3}{4}$		
	Strand chilled iron	30	10$\frac{3}{4}$	12,000			2·8	$\frac{1}{16}$	2000	$\frac{3}{4}$		
	Oval chilled iron	16	11$\frac{1}{2}$	8,000			1·4	$\frac{1}{16}$	500	1		
	Round chilled iron	16	11$\frac{1}{2}$	8,000			1·4	$\frac{1}{16}$	500	1		
	Roughing—grain	60	18$\frac{1}{2}$	30,000	10 for 1-in. dia. rounds	Copious water	3·2	$\frac{7}{16}$	9000	1$\frac{1}{8}$	1250	990
	Small roughing—alloy iron	36	12$\frac{5}{8}$	25,000			2·9	$\frac{1}{16}$	9000	$\frac{3}{4}$		
	Intermediate chilled iron	36	12$\frac{3}{4}$	30,000			2·8	$\frac{1}{16}$	6000	$\frac{7}{8}$		
	Strand chilled iron	36	13	40,000			2·8	$\frac{1}{16}$	7000	1		
	Oval chilled iron	18	12	10,000			1·5	$\frac{1}{16}$	100	1$\frac{1}{4}$		
	Round chilled iron	18	12	10,000			1·5	$\frac{1}{16}$	100	1$\frac{1}{4}$		

longer life of roll as measured in tons. The tonnage rolled and the amount turned off between dressings are also given. It will be seen that in general longer total life and life between dressing are achieved with the roughing and intermediate rolls than with the finishing rolls. Also, the total amount turned off during the life of the roll is less for the finishing rolls than for the roughing. This is not unexpected as greater accuracy is required in the finishing pass and these rolls will, therefore, be scrapped sooner because the grooves become oversize.

The dimensions of the rolls are given. The ratio of the length to the diameter varies from about 4·5 for roughing to 1·0 for finishing rolls. These ratios presumably give a satisfactory size of roll for rigidity. Flexing of the roll in the finishing pass must be reduced to the minimum and as a consequence these rolls have the smallest ratio of length to diameter. The diameters of the rolls vary from 36 in. for the largest billets to 9 in. for the finishing rolls.

The temperature of the section at the first and last pass is given. The drop in temperature during rolling is about 200–250° C. with an initial temperature of 1150–1250° C.

Further Examination of Reproducibility in Chemical Analysis

By J. O. Lay, A.R.I.C.

SYNOPSIS

A statistical comparison of results obtained in the evolution of standard chemical and absorptiometric analytical methods for manganese indicates the relationship between standard deviation and reproducibility of results and the contribution of certain factors to the variations found.

To assess the contribution of various factors to the reproducibility of results obtained by standard methods of analysis, attention has been especially devoted to the determination of manganese by chemical and absorptiometric procedures. A report on the development of the chemical procedure has already been published[1] and the method has been accepted by the British Standards Institution,[2] although certain minor modifications have been found desirable before the tentative standard absorptiometric method could receive the approval of the B.S.I.; the main details of the necessary investigation have also been described in a recent paper.[3]

An earlier contribution on this subject[4] drew a response from Rimmer,[5] which included a list of figures obtained during a research on the determination of aluminium in permanent-magnet alloys. Only one type of material was examined and the ten co-operating analysts were therefore each able to make ten replicate analyses, thus providing adequate data for statistical analysis. The American Society for Testing Materials, in outlining an inter-laboratory test programme, however, indicates[6] that the performance of a multiplicity of tests on a single material is not necessary for certain conclusions to be established.

As the investigations on manganese referred to above necessarily covered many types of iron and steel, a more limited programme had to be laid down and, in general, not more than three replicate analyses by each operator on each of ten different materials were practicable. The results permit of a modified statistical treatment if the premise that the presence of alloying elements has a negligible effect on the reproducibility of an analytical method (the ideal condition) is accepted, and the relevant data are summarized briefly in Tables I and II. It is evident that the assumption of the intrinsic analytical reliability of the operators concerned is adequately justified by the low and comparable average standard deviations calculated from their results on the range of samples tested.

Several of the same operators were concerned in the chemical analysis of the low-alloy steel series of spectrographic standards recently made available to industry,[7] and the standard deviations calculated from the series of results submitted (Table III) show satisfactory reproducibility for each of the elements

Manuscript received 6th September, 1950.

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Table I

CHEMICAL METHOD

Standard Deviation of Individual Operators and of Method

Sample	3	4	7	8	12	13	16	33	34a	35	Average Operator S.D.
Average Mn, %	0·938	0·645	0·399	0·284	1·525	0·468	9·197	0·690	0·132	0·109	
Operator:											
A	0·006	0·010	0	0	0·006	0·006	0·021	0·007	0	0	0·008
B	0·010	0·008	0·008	0·008	0·006	0·012	0·012	0·006	0·006	0·003	0·008
C	0·003	0·010	0·003	0·012	0·007	0·005	0·019	0	0	0·005	0·008
D	0	0	0	0·006	0	0·004	0·034	0·009	0	0·006	0·011
E	...	...	0·006	0·006	0·013	...	0·040	0·006	0·006	0·003	0·016
F	0·004	0·004	0·005	0·012	0·005	0·004	0·020	0	0·003	0	0·008
G	0·008	0·003	0·006	0·006	0	0·010	0·035	0·005	0·008	0·005	0·013
H	0·007	0·007	0·006	0·012	0·006	0	...	0·007	0	0	0·006
I	0·006	0·014	0·006	0·006	0·014	0·007	0·020	0·013	0	0·006	0·011
J	0	0·007	0·003	0·006	0	0	0·038	0·006	0·006	0·006	0·013
Average sample S.D. (within-operator)	0·006	0·008	0·005	0·008	0·007	0·006	0·028	0·007	0·004	0·004	0·011
S.D. of all readings	0·015	0·012	0·013	0·015	0·017	0·012	0·035	0·012	0·007	0·010	0·016

Table II

ABSORPTIOMETRIC METHOD

Standard Deviation of Individual Operators and of Method

Sample	13	15	17	34b	49	67	74	75	90	125	Average Operator S.D.
Average Mn, %	0·470	0·608	0·553	0·141	0·369	1·048	1·501	0·722	0·801	2·016	
Operator:											
K	0·004	0	0·006	0	0·001	0·006	0·012	0·021	0·006	0·006	0·009
L	0·006	0·013	0·003	0·002	0·003	0	0	0	0·003	0·006	0·005
M	0·005	0·005	0·006	0	0·003	0·008	0·006	0·009	0·009	0·010	0·007
N	0·004	0·007	0·003	0·005	0·011	0·006	0·006	0·006	0·002	0·026	0·010
O	0·003	0·003	0·006	0·010	0·003	0·012	0	0·006	0·003	0·015	0·008
P	0·005	0	0·005	0·001	0·003	0·006	0·012	0·006	0·010	0	0·006
Q	0·006	0·006	0·006	0·002	0·006	0·016	...	0·015	0·010	0·006	0·008
R	0	0·007	0	0·002	0	0·017	0·007	0·010	0	0·003	0·007
S	0	0·006	0·006	...	0·006	...	0·012	...	0·015	0·020	0·011
T	0·009	0·003	0·013	0	0·003	0·014	0·017	0	0·006	0·012	0·010
Average sample S.D. (within-operator)	0·005	0·006	0·006	0·004	0·005	0·010	0·009	0·010	0·008	0·013	0·008
S.D. of all readings	0·010	0·010	0·007	0·008	0·013	0·016	0·022	0·015	0·022	0·025	0·016

Table III

STANDARD DEVIATIONS OF WITHIN-OPERATOR RESULTS ON SPECTROGRAPHIC STANDARDS

Results are given in ascending order of element content
Horizontal lines indicate change of sample weight

Element and Range Covered						
Si	Mn	Ni	Cr	Mo	V	Cu
0·01–0·81, %	0·02–1·4, %	0·05–5·2, %	0·04–3·1, %	0·01–1·4, %	0·03–0·65, %	0·09–0·50, %
0·002	0·002	0·004	0·002	0·001	0·002	0·002
0·005	0·004	0·013	0·006	0·003	0·002	0·005
0·004	0·006	0·003	0·008	0·009	0·003	0·004
0·004	0·009	0·011	0·003	0·009	0·003	0·005
0·006	0·006	0·021	0·006	0·007	0·006	0·009
0·006	0·009	0·019	0·012	0·013	0·006	0·007
0·005	0·008	0·014	0·013	0·025	0·009	0·006
0·005	0·009	0·017	0·031	0·012	0·005	0·013

concerned, except, perhaps, molybdenum. This exception may logically be explained by the absence of a fully authenticated standard method at the present time, and an investigation is in progress to ensure the further improvement of the method actually employed.

A further point of particular interest is the relationship between the reproducibility generally quoted, which is based on the extreme range of results obtained by several reliable analysts, and the actual standard deviation found by calculation. In every case the reproducibility of reported results, claimed as the expected performance of the method, lies between $1{\cdot}0\sigma$ and $2{\cdot}0\sigma$, being usually just less than $1{\cdot}5\sigma$, and a relationship $2R = 3\sigma$ will be sufficiently accurate for most purposes. Since, as Fisher remarks,[8] the probable error of results may be represented by 0·6745 times the estimated standard deviation, a reproducibility of about twice this figure leaves a safe margin.

It appears, therefore, that having due regard to the analytical principles and tolerances involved, the attainment of a within-operator standard deviation of 0·010 and a grand standard deviation of 0·015, when checking a standard analytical method, is a sufficient indication of its satisfactory performance.

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Applications of the Statistical Analysis of Factors Affecting the Output of an Open-Hearth Furnace

By P. Arnold and M. W. Thring, M.A., F.Inst.P.

SYNOPSIS

The statistical analysis described in a paper by Robertson and Thring on factors influencing the output of an open-hearth furnace has been applied to further data and has given a relation between (*a*) the carbon content of the fully melted steel, (*b*) the weight of oxygen required to oxidize C, Si, P, and Mn in the original charge, and (*c*) the rate of oxidation. The effect on the output of increasing the flame radiation is twice as great if the oxygen equivalent of the initial charge, instead of being kept constant, is reduced by such an amount that the melt-out or 'junction' carbon is the same as it was with the original flame. It is also shown that if a method of feeding the carbon back to the charge in soft melts were available, a 5% gain in output would result from reducing the oxygen equivalent of the initial charge to give the average carbon at melt-out equal to the previous lowest permissible value.

OXYGEN EQUIVALENT

A FURTHER statistical analysis of results from the fully instrumented open-hearth furnace, subsequent to those described in a paper by Robertson and Thring* on factors influencing the output of an open-hearth furnace, has made it possible to state some conclusions of immediate practical application. In the earlier paper it was shown that for a fixed oxygen equivalent of the charge† improvements to the heating power of the flame have a marked effect on the time to junction‡ but have only a small effect on the final output because, although an improved flame causes the heating-up curve to overtake the oxidation curve earlier, a higher carbon content at junction results and the period between junction and tapping is increased. In some later work it has been possible to carry out a multiple correlation for the carbon content at junction with the rate of oxidation before junction, and with the oxygen equivalent of the original charge. The carbon content at junction depends to an even greater extent on the latter than on the former.

The formula relating these values is

$$C_J = 0{\cdot}54 + 0{\cdot}60\,(O_E - 2{\cdot}39) - 1{\cdot}20\,(O_N - 0{\cdot}54) \ldots (1)$$

where C_J is the carbon at junction, O_N is the rate of oxidation from start of charge to junction, and O_E is the oxygen equivalent of the original charge. Figure 1 shows this relationship for values of O_N covering the usual range in the casts analysed; the range of O_N corresponds to a change in C_J of about 0·25% (for fixed O_E), while that of O_E (2–2·8) corresponds to a change in C_J of about 0·45% (for fixed O_N).

In the earlier paper it was not possible to determine the relation between C_J and O_E either because there was less variation in O_E or because the analysis was less accurate, and it was concluded that the effect of improved flame radiation could be calculated only when the oxygen equivalent of the charge was held constant. It is now possible to calculate the effect of improving the flame radiation and simultaneously reducing the oxygen equivalent of the charge to retain the carbon content at junction at its original value. This process is economically feasible, provided that extra scrap is available, since scrap is cheaper than pig iron and the elements which give rise to the oxygen equivalent of the charge mainly enter in the pig. In this case, of course, the effect of improved flame-heating power on the total time will be exactly

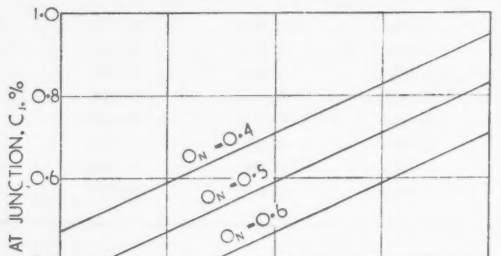


Fig. 1—Statistical relation between carbon at junction (C_J), oxygen equivalent of original charge (O_E), and the oxidation rate during period from start of charge to junction (O_N)

*F. L. Robertson and M. W. Thring, *Journal of The Iron and Steel Institute*, 1949, vol. 163, Sept., pp. 31–50.

†The oxygen equivalent is the weight of oxygen required to oxidize the C, P, Mn, and Si in the charge to CO, P_2O_5, MnO, and SiO_2; all weights are in tons.

‡The concept 'junction' is used to denote the condition in a cast usually described as 'fully melted' or 'melt-out' *i.e.*, the time at which the main process ceases to be the melting of the charge and becomes the removal of impurities from the fully melted charge. It is defined by the temperature rise of the charge overtaking the increasing refractoriness of the bath because of the gradual drop of carbon content. The actual process of overtaking corresponds to the achievement of a relationship between charge temperature and carbon content shown in Fig. 1 of the earlier paper.

Paper SM/A/62/50 of the Steel Practice Committee of the Steelmaking Division of the British Iron and Steel Research Association, received 19th June, 1950. The views expressed are the authors' and are not necessarily endorsed by the Committeee as a whole. Miss Arnold is in the Mathematical Section of the Physics Department of the Association and Mr. Thring is Head of the Physics Department.

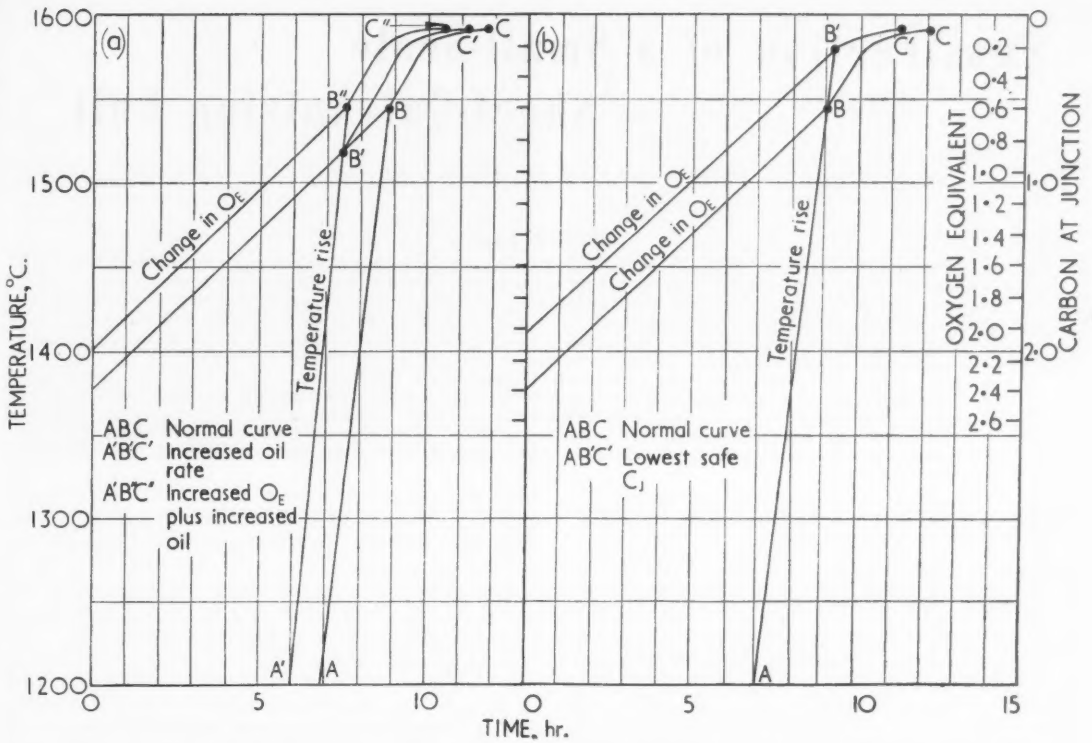


Fig. 2—Heating and oxidation curves for charges with (*a*) varying fuel rate and oxygen equivalent of charge, (*b*) varying oxygen equivalent showing effect of reducing average carbon content of steel at junction

equal to its effect on the time to junction. Curve $A'B''C''$ in Fig. 2*a* shows the effect when the oxygen equivalent is reduced to give the same carbon content at junction. In the earlier work the time to junction was reduced by 83 min.,* but the total time was only reduced by 38 min. (*see* curve $A'B'C'$, Fig. 2*a*) whereas with reduced oxygen equivalent the time to junction and the total time are both cut by 77 min. Any improvement in flame-heating power must therefore be accompanied by a change in the oxygen equivalent of the materials charged to the furnace.

CARBON CONTENT AT JUNCTION

If it is possible to reduce the scatter in the carbon content at junction or to find some method of dosing the furnace to bring back the carbon at junction, if it is too low for the other refining processes, then a lower value for the oxygen equivalent of the initial charge can be chosen so as to give a lower average carbon content at junction, and again the output can be increased. Thus in equation (1) for the existing furnace, the average value of the carbon content at junction is 0·54% but its standard deviation is 0·25%. It is therefore necessary to operate with this average value to avoid soft melts with a carbon at junction below 0·20% and, even then, they may occur. If however, the oxygen equivalent were readjusted to make the average carbon at junction equal to its lowest safe value, 0·20%, and the carbon were recharged in cases where it came out below this value, the gain in average total time would be 47 min. and the resulting gain in output 0·34 tons/hr. (*see* Fig. 2*b*). In this figure ABC is the existing curve and $AB'C'$ the revised one.

In this way, from statistical analysis it is possible to calculate the economics of a scheme which has often been proposed, namely adding carbon to the bath at melt-out or junction. Statistics also show the importance of controlling the oxidizing power of the flame and, in the first instance, of measuring it for future statistical analysis.

CONCLUSIONS

When making low-carbon steels with an all-cold charge, at present any gain through speeding up the melting process by increasing the flame-heating power is partially lost, because of higher junction (melt) carbon contents and longer refining time. To gain the full benefit of increased heating power in the flame, the scrap proportion should be increased to give the same average junction (melt-out) carbon content.

Increasing the scrap proportion beyond this point increases the risk of 'soft melts,' and therefore to realize fully the benefits of increasing the scrap proportion it is necessary to find some means of adding carbon rapidly in an emergency. Were it possible to devise such means, a considerable increase of output should be attainable.

* All numerical values are, of course, only applicable to the particular furnace concerned, but the relative results can be generally applied.

Construction of a Small-Scale Sheet-Galvanizing Unit

By M. L. Hughes, Ph.D., M.Sc., F.R.I.C., F.I.M., and I. E. Thomas

SYNOPSIS

To make a thorough study of the various aspects of the hot-dip galvanizing of sheets, experimental work is required which cannot conveniently be carried out in the works. Although manufacturers have been very willing to assist in this work it would be unreasonable to expect them to carry out experiments which would unduly delay production, produce unsaleable sheets, or reduce the life of the pot. For these and other reasons a small galvanizing unit, large enough to hold about 6 cwt. of zinc, has been constructed at the B.I.S.R.A. laboratories at Sketty Hall, Swansea. The unit was designed to galvanize sheets of 8 in. width and of any convenient length, in a manner essentially similar to that employed in industry.

After certain initial troubles, mainly due to the inevitable alloying of moving parts, sheets have been successfully galvanized at various speeds, bath temperatures, and bath compositions.

This report describes the construction of the unit, and, since it was not possible to base the design on any system of similarity principles, a fairly detailed account is given of the reasoning by which the final dimensions were determined.

FACTORS AFFECTING THE DESIGN OF THE UNIT

No previous information has been found on the design and operation of a small mechanized sheet-galvanizing unit. Most research workers investigating galvanizing appear to have limited themselves to a simple dipping process. The authors were compelled, therefore, to decide upon the dimensions and other factors without the assistance of any previous data.

The overall size was largely governed by the space available, the convenience of operation and, to some extent, the cost of the zinc required to fill the bath. (The zinc used is ultimately alloyed in such a way that its value is much reduced should it be subsequently sold.) It was decided, therefore, that 5 cwt. would be a reasonable amount and would provide a sufficient heat reserve for the purpose.

The length of the unit was dictated by the requirement that the temperature of the sheet must reach that of the bath during its passage from the entry to the exit rolls. This also involves the speed and the gauge of the sheet. To compensate for the shorter distance traversed by the sheet while immersed in the zinc, as compared with industrial practice, slower speeds or thinner sheets, or both, are used to ensure adequate heating. The gauge of the sheet is considered to be of much less importance than the speed as a process variable, and it was decided to work with 26-gauge sheet (0·018 in. thick), or thinner, and to limit the maximum speed to 40 ft./min., which is within the range of industrial speeds. An immersed path of 2–3 ft. should give sufficient time for adequate heating, and is not very much less than that traversed by the sheet in some older production units working without bottom rolls.

Information on the time necessary for the central plane of the sheet to reach a steady temperature has long been needed. It appears to be a difficult heat-conduction problem, because of the initial freezing of a film of zinc around the sheet and because of uncertainty regarding the coefficient of heat transfer.

The width of the unit was now defined, since the volume of zinc and the length of the pot were fixed; the maximum width of sheet which can be processed is $7\frac{7}{8}$ in. The opportunities for studying transverse variation are thus limited, but previous distribution studies on industrially galvanized sheets indicate that this type of variation is much less serious than longitudinal and interfacial variation.*

The exit rolls represented an entirely separate and difficult problem. It was necessary to decide the diameter of the rolls and the dimensions of the grooves. The conditions at the nip of the exit rolls have an important bearing on coating thickness and distribution. The shape of the space immediately above the nip and the volume of metal corresponding to a given height above the nip both change with roll diameter, and to reduce this scale factor as much as possible the roll diameter was made as large as would be convenient. Accordingly, 3-in. dia. rolls have been adopted and, for the initial experiments, are being used without grooves. Additional rolls with grooves have been made and it is hoped to obtain some information on roll grooves and their influence on coating results. Shielding collars protect the metal in the nip from contamination by scum.

The usual spring method is used for applying and varying the pressure on the exit rolls. The springs have been calibrated and the rotating collars which compress them are graduated and move under an index pointer.

In Figs. 1, 2, and 3 bottom rolls are shown driven by a train of gears. This drive was employed because there was insufficient side clearance for the worm gear drive originally intended, but these gears caused considerable trouble in the early experiments, largely

Paper MW/C/58/49 of the Coatings Committee of the Mechanical Working Division of the British Iron and Steel Research Association, received 2nd May, 1950.

Dr. Hughes is Head of the Metallurgy Section and Mr. Thomas is in charge of the workshop at the Association's South Wales Laboratories, Sketty Hall, Swansea.

* M. L. Hughes, "Survey of Coating Thickness Variations on Commercially Galvanized Sheets." B.I.S.R.A. Paper MW/C/2/49.

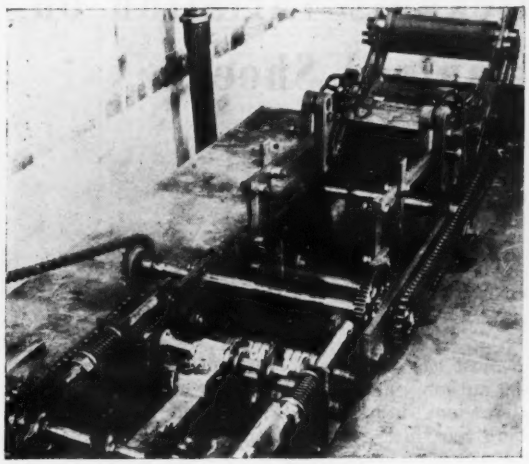


Fig. 1—General view of rig in position, showing inlet and exit rolls, drive, and front end of conveyor. Certain modifications have been made since this photograph was taken

due to excessive alloying leading to seizure. This was accentuated by the unsuitable composition of some of the gears used and it was therefore decided to work without bottom rolls; this eliminated the train of gears.

MATERIALS OF CONSTRUCTION

The pot and the various parts of the machine are made from dead soft steel to minimize alloying action. Nickel steel was tried for the side gears, but, as mentioned above, growth due to alloying proceeded at an astonishing rate. With unalloyed steel gears a considerable improvement was seen. The original gears contained 3·2% of nickel, as well as 0·33% of carbon and 0·23% of silicon. Thus any advantage due to the nickel was apparently swamped by the well-known accelerating action of carbon and silicon, especially the latter.

The pot, of welded construction, is made from $\frac{3}{4}$-in. thick steel.

In practice the flux box is usually subjected to severe attack by the combined action of molten zinc and flux. At first it was thought that special material should be used for the box, but ordinary low-carbon steel sheet was finally used, since the actual working time would not be great and replacement would be cheap and simple. The unit has been in use for varying periods on four or five occasions and the flux box is still in a usable condition.

The usual squeegee and entry rolls are provided at the feeding end, with a 'star-wheel' conveyor at the exit end, as shown in Figs. 1 and 2.

The drive is provided by a 3-h.p. motor *via* a three-speed gear-box. By using a second sprocket there is a choice of six sheet speeds, *viz.*, 6, 9, 15, 18, 27, and 40 ft./min. Some of these speeds are lower than those used in industrial practice, but they are nevertheless of interest since the best industrial distribution results were obtained at the slower speeds. The effect of a further reduction in speed on coating distribution has been examined and the tendency towards better results has been confirmed.

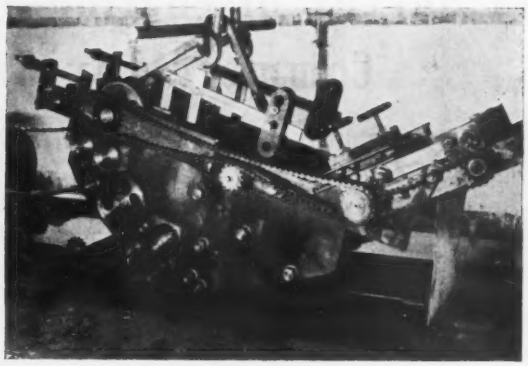


Fig. 2—Close-up of rig. The bottom rolls and the train of gears for driving them are not at present in use

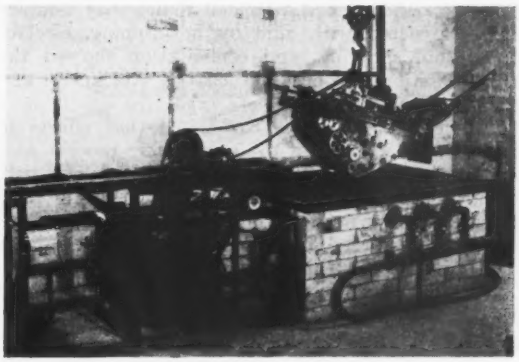


Fig. 3—View showing gas jets and conveyor. The drive has been removed from the position shown and is some distance to the left. The drive is transmitted by a shaft resulting in much smoother operation

HEATING ARRANGEMENTS

The pot is heated by seven Selas gas burners using town gas; there are three burners on each side and one at the entry end. The arrangement is shown in Fig. 3.

To avoid local overheating of the pot, sheets of heat-resisting steel are hung at the sides and front between the gas flames and the pot, quite close to the latter. The flames impinge obliquely on these sheets. Some thermal efficiency is no doubt sacrificed by this arrangement, but the pot can be heated moderately quickly.

CONCLUSION

Sheets have been successfully galvanized in this machine and have been examined for coating distribution, structure, and 'adhesion.' The standard size of sheet used in the experiments is 30 × $7\frac{7}{8}$ in., but strips up to 20 ft. long and the same width have also been successfully treated.

A Survey of Coating-Thickness Variation on Commercially Galvanized Sheets

By M. L. Hughes, Ph.D., M.Sc., F.R.I.C.

SYNOPSIS

In view of the close relationship between the thickness and the protective value of zinc coatings, an examination of the distribution of coating thickness on representative samples of commercially galvanized steel sheets has been made. The results of measurements along, across, and upon either side of the sheets are reported, and the probable relationship between the different types of thickness variation observed and existing techniques of galvanizing is discussed.

Introduction

It has been shown[1, 2] that the protection provided by a zinc coating is mainly decided by its thickness ; the method of application and, within limits, the purity of the coating are of less importance. For example, Hudson and Banfield[1] found that samples of steel coated with zinc by hot-dipping, electrodeposition, spraying, and cementation showed the same relationship between coating thickness and useful life.

In view of this, it is considered that efforts to improve the efficacy of the galvanizing process as a method of protection should be directed primarily towards increased control of the coating thickness and more especially its uniformity, since the measure of protection afforded by this coating will be largely determined by its thinnest portions.

Very little information seems to be available about the uniformity of coating normally to be expected on hot-dipped low-carbon steel sheets (galvanized sheets). A variation of 17½% is described by Camp and Francis[3, 4] as 'good commercial practice,' whilst according to A.S.T.M. specification *A*93.46 the minimum coating determination by a single spot test is allowed to be 20% below the average for the sheet, which is itself allowed to be lower than the ordered coating weight. The extensive literature on the galvanizing process does not appear to include a systematic study of the origin and magnitude of variation in coating thickness. There are passing references such as that of Cook,[5] who states that a high galvanizing speed leads to a heavier coating at the front end, which sets a limit to production speed when making 'tight,' *i.e.*, adherent, coatings.

To obtain more information about the nature and occurrence of variations in coating thickness of commercially galvanized sheet, sample sheets have been obtained from nine works, and the distribution of the coating on them has been systematically examined.

EXAMINATION OF GALVANIZED SHEETS

SAMPLING

The sample sheets represent normal production ; in most cases they are consecutive sheets taken by the author from the conveyor, or elsewhere, entirely at random ; in other cases the sheets being processed were too thick for the author's blanking press and the sampling was carried out by the works staff and the sheets were then sent to the author's laboratory. The upper face of each sheet as galvanized was marked.

Three or four sheets were usually taken, partly as a check on sheet-to-sheet variation and partly in case any of them proved to be defective and unrepresentative.

Samples have been obtained more than once from some firms. In one case four lots of sheets have been obtained, one set being experimental, over a period of about eight years. The form of the coating distribution, which is somewhat abnormal at this works, has not changed appreciably over this period.

A code is used to identify the works, the batch, the number of the sheet, and the position of the sample. For example, in the code number *A*/3/2 :

A = works *A*
3 = third group or batch of sheets
2 = sheet 2

Margins 1-in. wide were cut off the sides and the front of each sheet. Strips 3 in. wide were then cut in the length of the sheet, from the left, middle, and right. These were further cut into 3-in. squares, commencing with the front end of the sheet, until a small residual piece was obtained which included the list end of the original sheet. (*See* Fig. 1.)

COATING THICKNESS DETERMINATION

Discs 7 cm. in dia. were blanked out from the 3-in. squares for coating determination by a stripping method using a 2% solution of antimony trioxide in hydrochloric acid.[6]

To determine the coating on each face separately it was necessary, after weighing a disc, to lacquer one face,* strip the other, remove the lacquer, and reweigh.

In the early stages of the work five strips were sometimes examined ; the location of the extra strips is shown dotted in Fig. 1, which illustrates the sampling of a sheet 72 in. long by 30 in. wide. In some of these early tests the choice of strip varied, as will be seen, and distinction between faces was not always made.

Paper MW/C/2/49 of the Coatings Committee of the Mechanical Working Division of the British Iron and Steel Research Association, received 2nd May, 1950.

Dr. Hughes, Head of the Metallurgy Section, is at the Association's South Wales Laboratories, Sketty Hall, Swansea.

* 'Necol' varnish was quite effective.

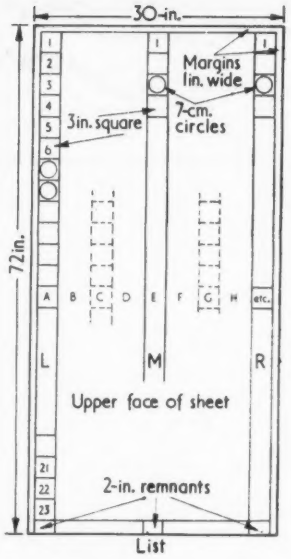


Fig. 1—Sampling diagram

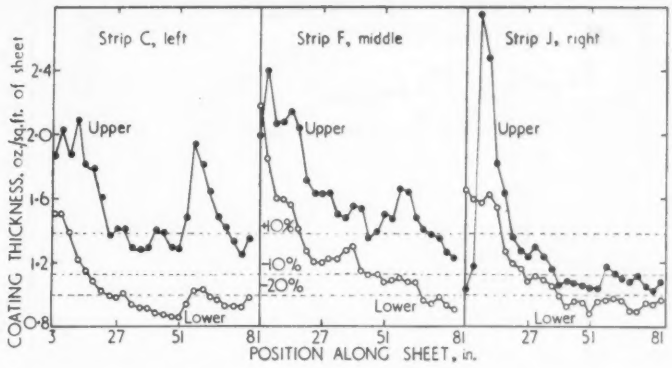


Fig. 2*b*—Sheet *A*/1/1. Interfacial difference on three strips. Broken lines indicate the limits 1¼ oz./sq. ft. ± 10% and − 20%

The weights of the steel discs after stripping both sides have been used to calculate the ' substance ' or thickness of the steel sheet. Variation in sheet thickness, especially across the width, may have a bearing on coating variation across the width, as stated below. This steel variation arises from the use of slightly concave rolls in pack-rolling the steel sheets.

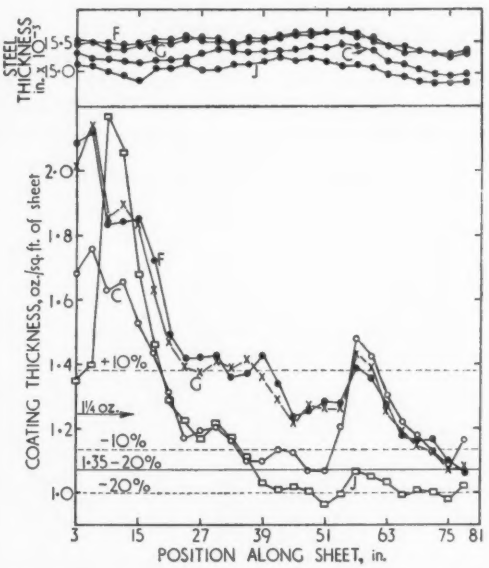


Fig. 2*a*—Sheet *A*/1/1. Variation of coating (both faces together) and of steel thickness. Broken lines indicate the limits 1¼ oz./sq. ft. ± 10%, the full line indicates the sheet average − 20%

PRESENTATION OF RESULTS

Coating thickness is expressed in ounces per square foot, which means, as is usual in the sheet-galvanizing industry, per square foot *of sheet* and not of surface. (A thickness of 0·001 in., or 1 mil, of zinc corresponds to 0·6 oz./sq. ft. of surface, which would be expressed as 1·2 oz./sq. ft. of galvanized sheet. The figures given in the accompanying graphs are thus easily converted to mils by dividing by 1·2.)

The results are plotted against position on the sheet in two ways :

(1) By taking the coating on both faces together and comparing the coating variation for the three or more strips with the steel thickness variation for the same strips, which is plotted on the same diagram. An increase in steel thickness at a given position might mean an increased pressure when passing through the exit rolls, leading to a reduction in the thicknesses of the two films of molten zinc on the sheet.

(2) By plotting each strip separately, showing the result for each face.

Having obtained the mean result for all the tests made on a sheet, the values ± 10% and ± 20% of this average are obtained and in most cases are marked on the graphs as horizontal dotted lines. The limits ± 10% represent a high standard of coating uniformity, ± 20% a satisfactory result by present standards. Results outside the − 20% boundary are to be considered as unsatisfactory, but it must be borne in mind that manufacturers often arrange for the total coating to be somewhat greater than is specified in order to take care of the poorer areas. Results below the author's 20% limit may thus be within − 20% of the specified coating thickness. (It is clear that any improvement in galvanizing technique leading to greater uniformity of coating would eliminate the necessity for this safety factor of additional zinc and would represent considerable monetary saving.)

SAMPLES FROM INDIVIDUAL WORKS

Works *A*, Group 1

The first group of sheets was received from works *A* in 1940. They were provided by the manufacturer and consisted of three sheets described as having a

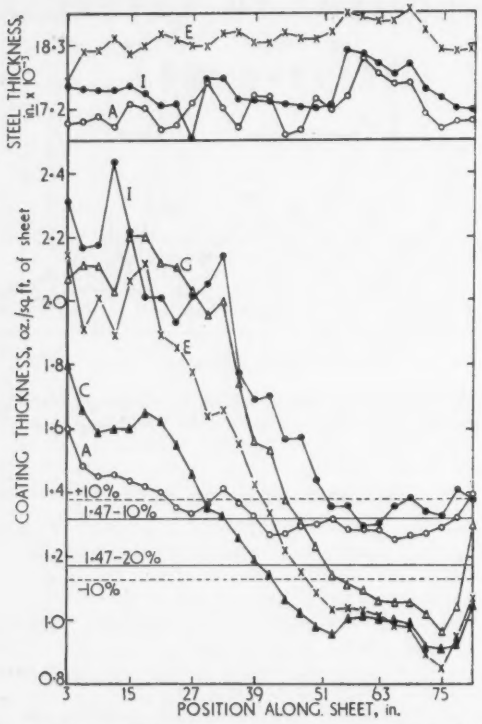


Fig. 3—Sheet *A*/2/1. Variation of coating (both faces together) and of steel thickness. Broken lines indicate the limits 1¼ oz./sq. ft. ± 10%, full lines indicate the sheet average — 10% and — 20%

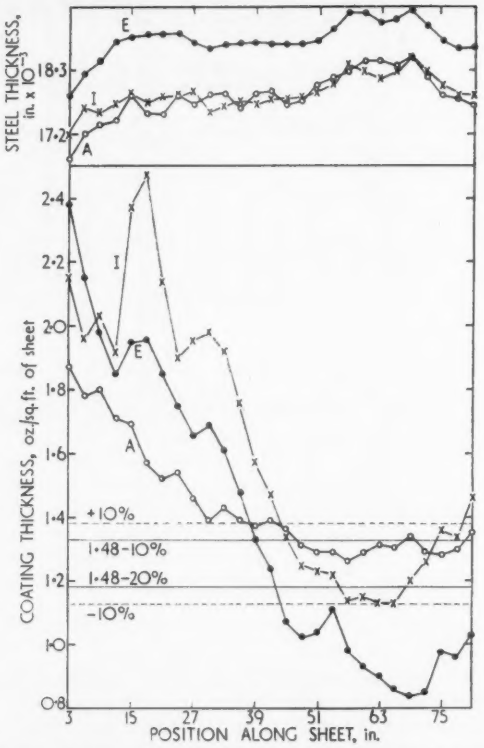


Fig. 4*a*—Sheet *A*/2/2. Variation of coating (both faces together) and of steel thickness. Broken lines indicate the limits 1¼ oz./sq. ft. ± 10%, full lines indicate the sheet average — 10% and — 20%

'1¼-oz.' coating and measured 84 × 36 in. (The results are incomplete because part of this group was destroyed in 1941 by enemy action.) Results for one of these sheets are shown graphically in Figs. 2*a* and *b*. *See* also Tables I, II, and III (pp. 60 and 61).

Figure 2*a* shows the coating variation along four strips from sheet *A*/1/1. Two strips were from the centre and the other two were mid-way between the centre and the edges. The coating for both faces together diminishes rapidly over the front third of the length. The central strips have a thicker coating, despite the greater steel thickness shown in the upper diagram. Broken lines indicate the specification limits, 1¼ oz. ± 10%, and also the — 20% limit. A few results on strip *J* are below the — 20% limit. The average coating for the whole sheet is 1·35 oz., and the limit of 20% below this is also shown.

Figure 2*b* shows the difference between the two faces of three of the strips from sheet *A*/1/1. There is appreciably less coating on the lower face and a considerable number of results for strips *C* and *J* are below the limit 1¼ oz. — 20%.

Works *A*, Group 2

A second batch of three sheets was provided by works *A* late in 1941. They were 84 × 30 in., were slightly heavier in gauge than the first batch,

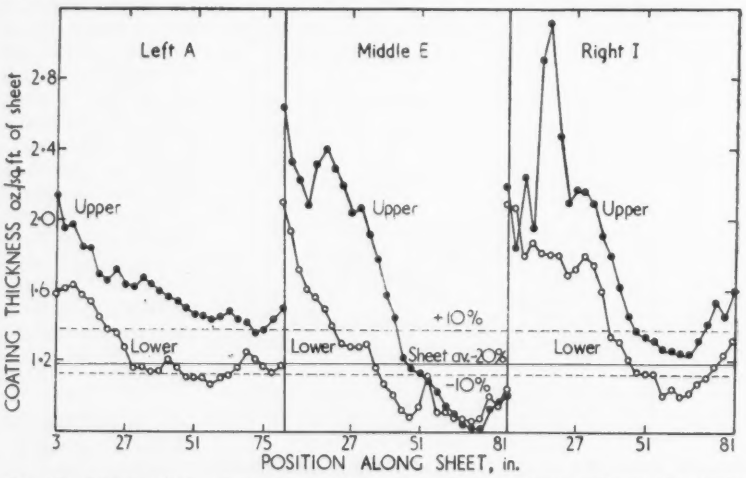


Fig. 4*b*—Sheet *A*/2/2. Interfacial difference. Broken lines indicate the limits 1¼ oz./sq. ft. ± 10%, the full line indicates the sheet average — 20%. Note the resemblance to Fig. 2*b* (sheet *A*/1/1)

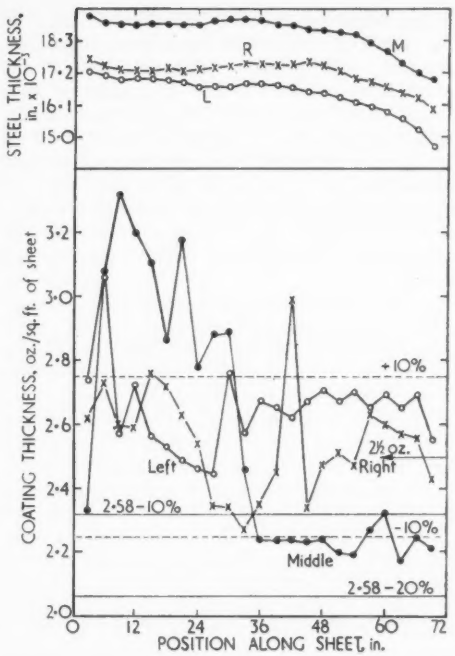


Fig. 5*a*—Sheet *A*/3/1. Variation of coating (both faces together) and of steel thickness. Broken lines indicate the limits 2½ oz./sq. ft. ± 10%, the full lines indicate the sheet average — 10% and — 20%

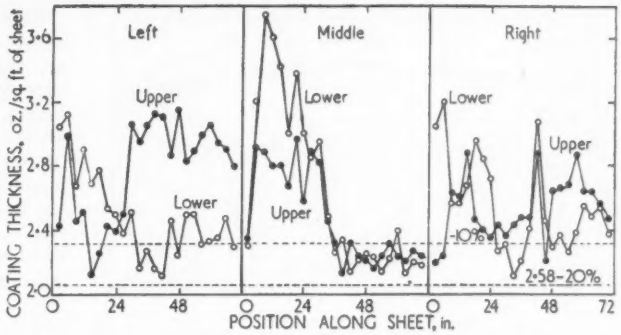


Fig. 5*b*—Sheet *A*/3/1. Interfacial difference. Broken lines indicate the sheet average — 10% and — 20%

and carried a little more zinc. In view of the marked variation on the first sheet of group 1, one of the second group was examined along five strips symmetrically disposed across the sheet, and the others at the centre and edges only. The results are given in Figs. 3, 4*a*, and 4*b*.

In Fig. 3, sheet *A*/2/1, the steep fall in coating value towards the rear is again found and it now continues much farther along the sheet. At the front there is a steady increase in coating thickness across the sheet to the right. There is now some evidence of a thinner coating in the central region, as compared with the edges, and the increase in steel thickness at the centre is more pronounced on this sheet. As before, the broken lines represent the limits 1¼ oz. ± 10%. A number of results are below 1·0 oz., which is 1¼ oz. — 20%. This is without separating the results into upper and lower faces and it is clear

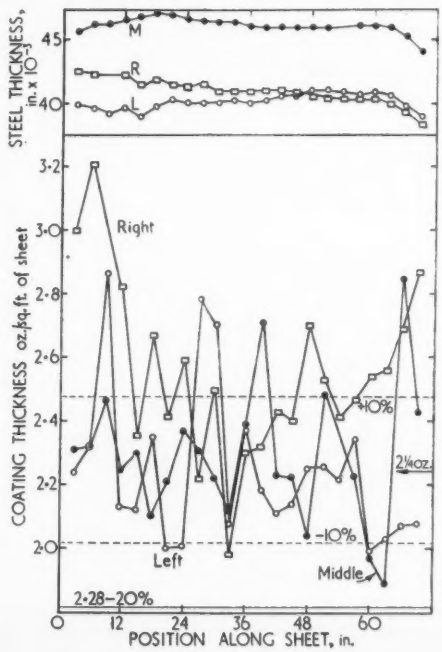


Fig. 6*a*—Sheet *A*/3/3. Variation of coating (both faces together) and of steel thickness. Broken lines indicate the limits 2¼ oz./sq. ft. ± 10%, the full line indicates the sheet average — 20%

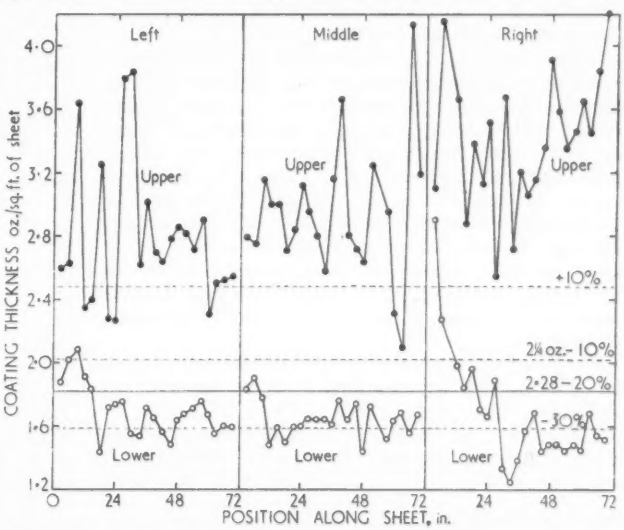


Fig. 6*b*—Sheet *A*/3/3. Marked interfacial difference. Broken lines indicate the limits 2¼ oz./sq. ft. ± 10%, the full lines indicate the sheet average — 20% and — 30%

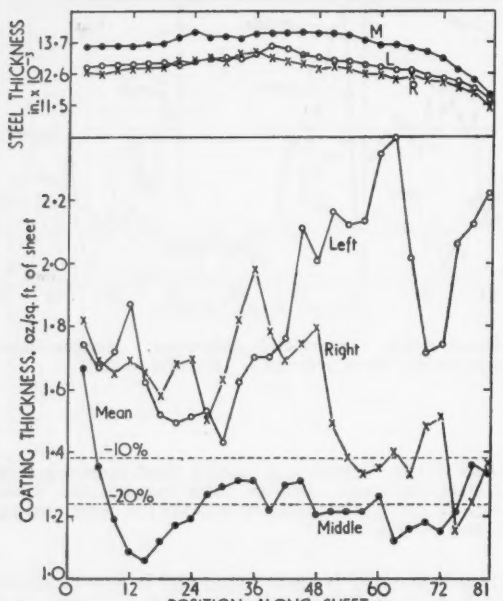


Fig. 7—Sheet *A*/3/4. Variation of coating (both faces together) and of steel thickness. Broken lines indicate the sheet average — 10% and — 20%

that much of this sheet is more than 20% below 1¼ oz., despite the fact that the average for the whole sheet is 1·47 oz./sq. ft. Since we are chiefly concerned with the variance of the coating as actually applied and not as specified, lines are drawn at (*a*) and (*b*) in Fig. 3 to represent 10% and 20% below the average value for the sheet.

Figure 4*a*, sheet *A*/2/2, gives the results for three strips, and the resemblance to Fig. 3, sheet *A*/2/1, is striking. The thinner coating at the rear of the centre strip, as compared with the edges, is again noticeable, and the gauge variation of the sheet resembles that of sheet *A*/2/1. This effect does not appear to arise until the coating thickness has diminished to what may be called its stabilized value ; although the steel thickness at the two edges is almost identical there is no resemblance in the curves for coating variation. The average coating for this sheet is 1·48 oz./sq. ft., almost identical with that of sheet *A*/2/1.

Figure 4*b* shows that interfacial difference of about the same order is again found. Note the resemblance to Fig. 2*b*, sheet *A*/1/1.

The results obtained for the third sheet in this batch also gave very similar results. *See* Tables I and II.

Works *A*, Group 3

Group 3 included sheets of several steel thicknesses and the coating weight was increased in order to see whether the nature of the distribution varied with the class of product. The sheets were processed in the usual way, the speed being varied according to the thickness of the sheet. The results are plotted in Figs. 5*a*, 5*b*, 6*a*, 6*b*, and 7.

The mean value for sheet *A*/3/1, Fig. 5*a*, is 2·58 oz./sq. ft. Most of the results, both faces combined, are above the — 10% limit. The rear half of the centre strip falls between the — 10% and — 20% limits. This sheet could have been sold as a 2½-oz. sheet, which would almost satisfy a lower limit of — 10%. This is highly satisfactory and is a marked improvement on the previous results. The form of the coating variation has altered : although there is still a decrease towards the rear, it is much less and is more gradual. To produce this thick coating considerably more zinc must have been at the nip of the exit rolls and this would appear to be the main factor, although the possible influence of steel thickness again appears. The steel thickness is slightly less than in the previous group, but would involve little, if any, change in the processing speed.

Figure 5*b* shows that the interfacial difference is also different in character. The lower-face results are not now consistently less. There is a marked difference between the front and rear halves of the middle strip and this is difficult to explain. The limits shown are — 10% and — 20% on the sheet average and, even after separation into separate faces, not one result is below the — 20% limit.

Sheet *A*/3/3, Fig. 6*a*, has an average coating of 2·28 oz./sq. ft. The steel is thinner, but is still of appreciable thickness. The variation in coating thickness is more erratic than in the previous examples. An impression of fairly satisfactory distribution, as compared with the sheets of groups 1 and 2, is given by these results, and the true position is not seen until interfacial difference is examined. Figure 6*b* shows that, actually, the distribution is very bad. Whereas Fig. 6*a* suggests that the sheet would be a good 2¼-oz. sheet, very few results being more than 10% below,

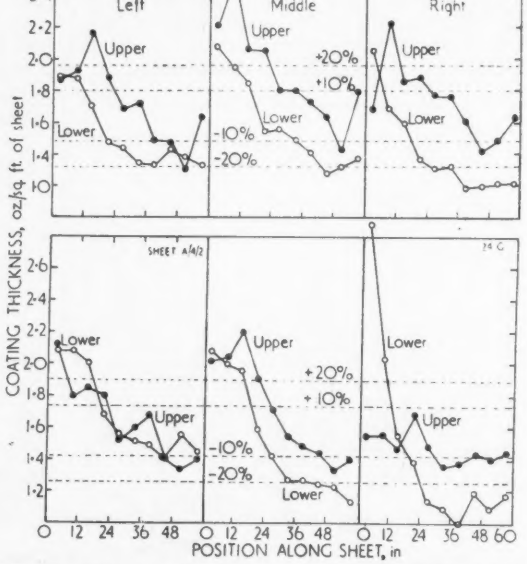


Fig. 8—Sheets *A*/4/1 and 2. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

on the lower sides the three strips examined have only three results out of 69 within that specification and most of the others are well below it.

In sheet *A*/3/4, Fig. 7, the steel thickness is reduced to 0·0126–0·0132 in., and the average coating has dropped to 1·55 oz./sq. ft. The coating variation is again fluctuating, but the fluctuation is less rapid than on the other sheets in this group. The most striking feature is the marked decrease in coating on the middle strip. *See* also Figs. 3 and 4*a* (rear). This is again seen on sheets *C*/1/1, Fig. 12*a*, and *D*/2/1, Fig. 15.

Works *A*, Group 4

Effect of Sheet Gauge—When the sheet to be galvanized is thick the speed of galvanizing is reduced to ensure adequate heating. This variation in speed of galvanizing makes it difficult to determine the possible influence of sheet gauge on total coating and on coating variation by examining normally produced sheets.

A batch of six sheets (*A*/4/1 to 6), varying from 16 gauge* to 27 gauge, was therefore specially processed at constant speed. The sheets were trimmed to the same size so that the mass would be proportional to thickness in each case. The overall coating averages on the sheets (means of 30 tests on each face of each sheet) were:

Gauge	27	24	22	20	18	16
Coating, oz./sq. ft.	1·64	1·58	1·50	1·50	1·73	1·80

Figures 8, 9, and 10 show the distribution of the coating on these sheets. Sheets 1, 2, 3, and 5 have a distribution similar in general form to that of groups 1 and 2, which were sampled seven and six years earlier, respectively. Sheets 4 and 6 differ in some respects. Longitudinal variation is bad in all

* The Birmingham Sheet and Hoop Gauge is used throughout this work.

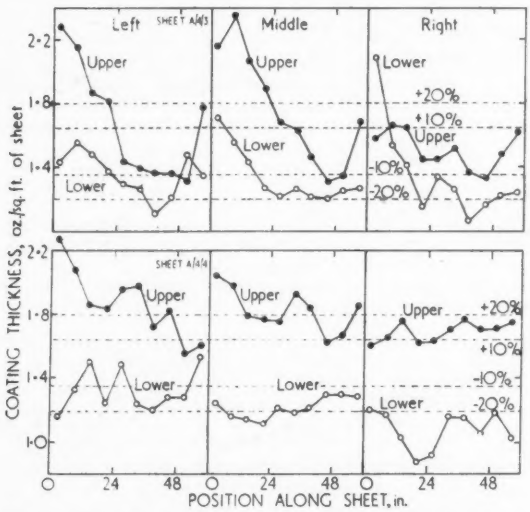


Fig. 9—Sheets *A*/4/3 and 4. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

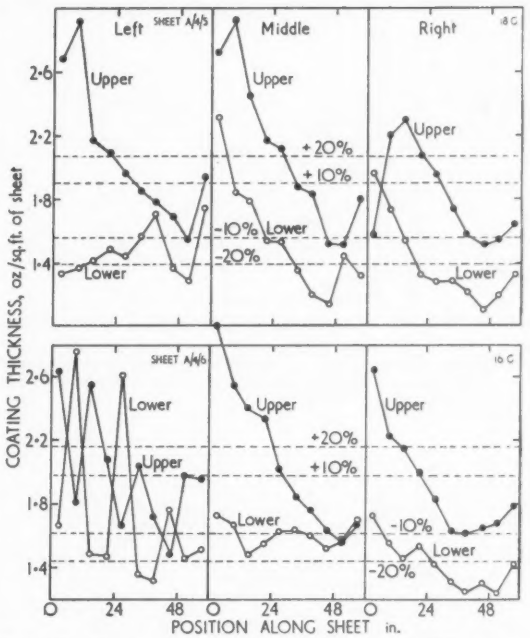


Fig. 10—Sheets *A*/4/5 and 6. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

except sheet 4, and interfacial difference is high in all cases. All six sheets fail to meet the specification of sheet average, — 20%, when this difference is allowed for. Taking *mean* values, sheet *A*/4/4 would meet a — 10% limit (Fig. 9).

The results for works *A* are inferior to those for most of the other works, but they are of considerable interest as they show, in an exaggerated form, the variations which arise in other works and are of value to those interested in the mechanism and the control of hot-dipping processes.

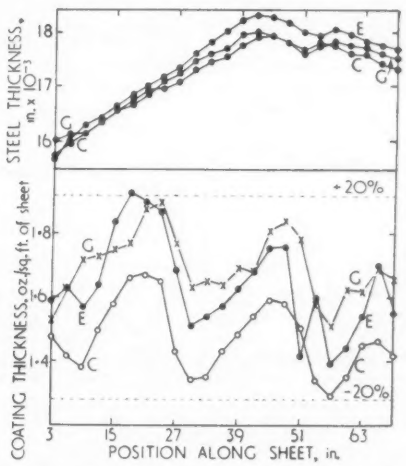


Fig. 11—Sheet *B*/1/1. Variation of coating (both faces together) and of steel thickness. Broken lines indicate the sheet average ± 20%

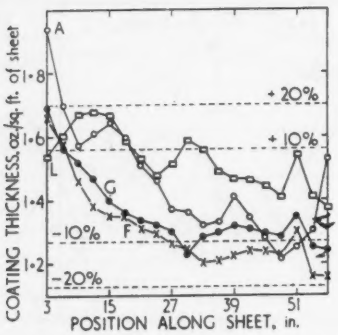


Fig. 12*a*—Sheet *C*/1/1. Variation of coating (both faces together). Broken lines indicate the sheet average ± 10% and ± 20%

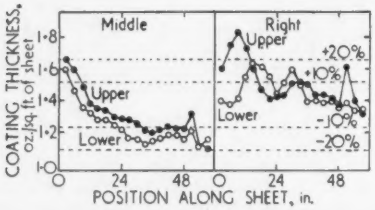


Fig. 12*b*—Sheet *C*/1/1. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

Works *B*

Three consecutive sheets were obtained from works *B*, but enemy action destroyed the samples when only one sheet and one strip from a second sheet had been examined.

The results for sheet *B*/1/1 are given in Fig. 11. The mean result is 1·60 oz./sq. ft., and when both faces are taken together, as here, the sheet satisfies the specification of ± 20% of the sheet average. The thickness of the steel shows marked variation without appearing to affect the coating distribution. Interfacial difference (not shown here) is reasonably good, but is sufficient to cause the left strip to fall below the 20% limit in two places.

Although only a single strip was examined on the second sheet it is enough to show that the results are similar to those of the first sheet. The sheets of a batch have usually been found to be remarkably similar.

It has not been possible to obtain further samples from this works because they have not recommenced galvanizing operations since the war.

Works *C*, Group 1 (One Sheet)

A single sheet (*C*/1/1) was taken from stock at works *C* in March, 1945. Face distinction is therefore arbitrary, no attempt being made to decide the original upper and lower faces. In any case, the difference in coating thickness on the two faces is small.

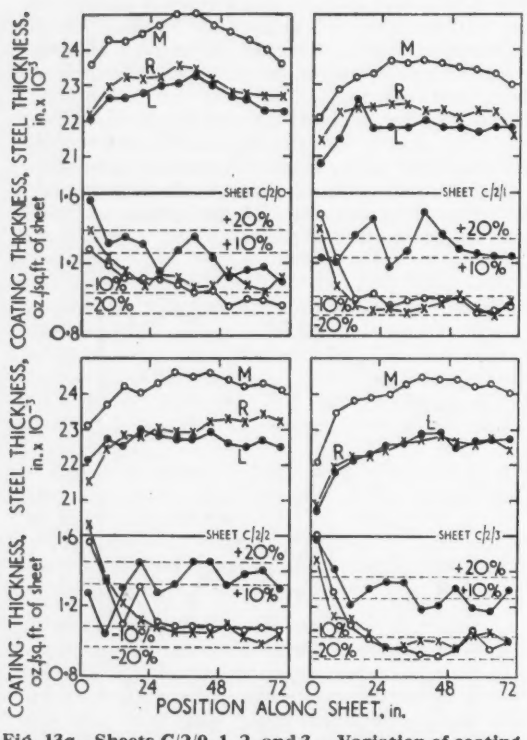


Fig. 13*a*—Sheets *C*/2/0, 1, 2, and 3. Variation of coating (both faces together) and of steel thickness. Note the left-hand strips. Broken lines indicate the sheet average ± 10% and ± 20%

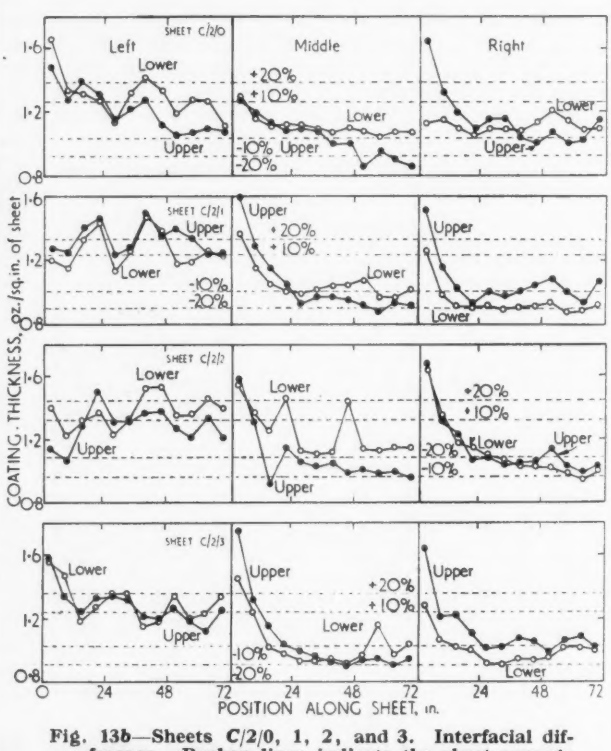


Fig. 13*b*—Sheets *C*/2/0, 1, 2, and 3. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

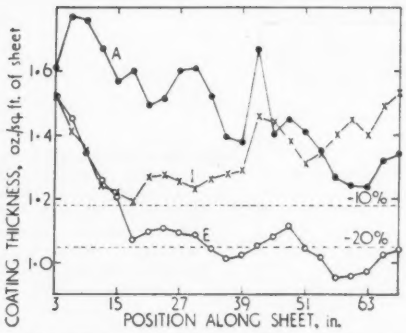


Fig. 14*a*—Sheet *D*/1/1*b*. Variation of coating (both faces together). Broken lines indicate the sheet average — 10% and — 20%

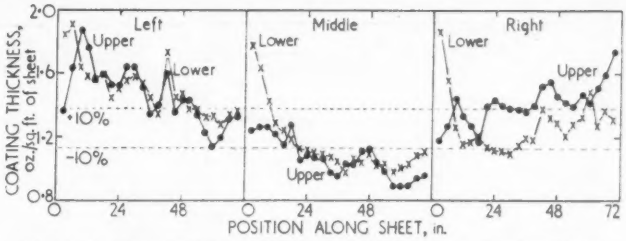


Fig. 14*b*—Sheet *D*/1/1*b*. Interfacial difference. Broken lines indicate the limits 1¼ oz./sq. ft. ± 10%

From Fig. 12*a*, coating distribution is seen to be within the — 20% limit based on the average result of 1·43 oz. The front excess, seen in the sheets from works *A*, is present, but less in amount ; the central strips are poorer than those at the edge for most of their length (*cf.* Fig. 7). Interfacial difference, shown in Fig. 12*b* for one central and one edge strip only, is sufficiently small to allow the results to remain above the — 20% limit.

Works *C*, Group 2

In February, 1948, four sheets (*C*/2/0 to 3) were taken during actual production at works *C*. It may be thought that the agreement between sheets sampled together is due to the fact that they all come from the same hot-rolled pack. However, it is difficult to see how this could happen on so many occasions and in any case the sheets in a pack are likely to vary in surface condition and in other respects. On this occasion a single sheet was first taken and, after a considerable interval, three sheets were taken in succession, as usual. The first sheet was necessarily from a different pack of steel sheets, whereas the group of three may or may not have been from one pack. The sheets were numbered 0, 1, 2, and 3 and were examined in the usual way. The results for the single sheet were in excellent agreement with those for the other three, as shown by Figs. 13*a* and *b*. The extra thickness at the centres of these sheets does not appear to have had any appreciable effect. In all but a few results the sheets meet the — 20% limit.

Comparison with the results for the earlier sheet shows that there is a distinct resemblance, despite the reduced coating thickness. The form of the distribution curves, the higher value and fluctuations of one edge curve, and the low interfacial difference, are similar on both occasions.

A marked feature of the batch of four is the thicker coating on the left edge, which may be related to the fact that the drive is on that side.

Works *D*

Works *D* is represented by two sheets only, taken on separate occasions. Results for the first sheet, *D*/1/1*b*, are given in Fig. 14*a*, showing the marked deficiency along the central strip previously observed, and in Fig. 14*b*, where interfacial variation is very satisfactory. This sheet had an average coating, based on 69 tests on each face, of 1·31 oz./sq. ft., but would not meet a specification of 1¼ oz. ± 20%. This is mainly due to transverse variation, *i.e.*, central deficiency. The sheet was thin, 30 gauge, and measured 72 × 28⅝ in.

The second sheet, *D*/2/1, was 26 gauge and 96 in. long. The results in Fig. 15 show a remarkable resemblance to those of sheet *D*/1/1*b*, Fig. 14*a*, the thinner coating on the centre strip again being very marked. The average coatings on the left, middle, and right strips are 1·42, 1·12, and 1·67 oz./sq. ft. ; the corresponding values for sheet *D*/1/1*b* were 1·49, 1·12, and 1·34 oz./sq. ft. (*See* also Table I.) This agreement between sheets sampled on different occasions has been referred to earlier under the sections dealing with works *A* and *C*.

Works *E*

All the sheets so far mentioned were galvanized in baths containing only a small amount of tin, *e.g.*, 0·1–0·2%, to improve spangle. Heavier additions of tin are often made when the coated sheet has to

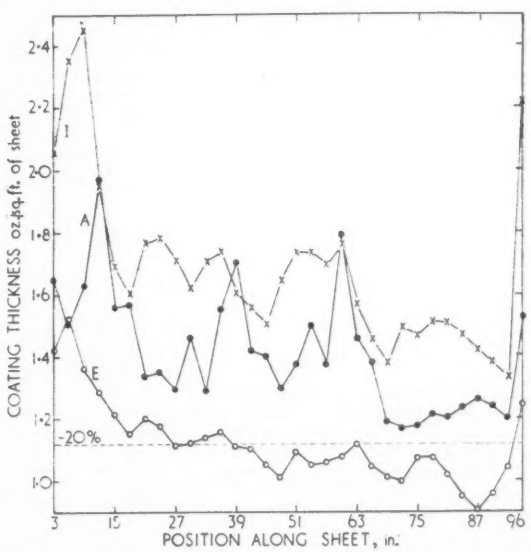


Fig. 15—Sheet *D*/2/1. Variation of coating (both faces together). Broken line indicates the sheet average — 20%

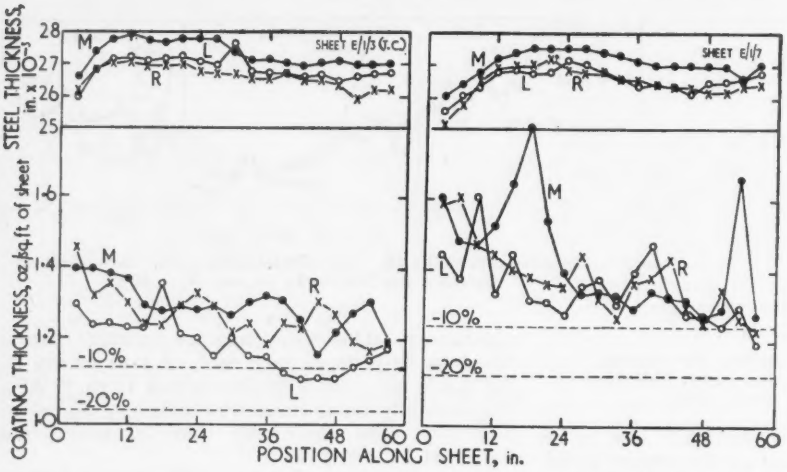


Fig. 16*a*—Sheets *E*/1/3 and 7. Variation of coating (both faces together) and of steel thickness. Sheet 3, 'tight-coated'; sheet 7, ordinary coating. Broken lines indicate the sheet average — 10% and — 20%

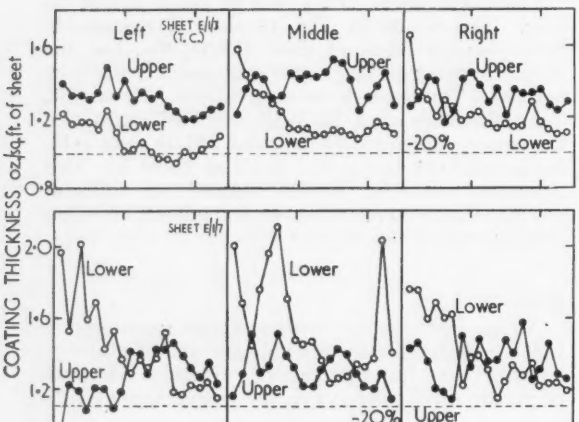


Fig. 16*b*—Sheets *E*/1/3 and 7. Interfacial difference. Sheet 3, 'tight-coated'; sheet 7, ordinary coating. Broken lines indicate the sheet average — 20%

be fabricated. High-tin baths seem to be more fluid and the coating thickness and distribution may be affected.

By the co-operation of works *E*, the coating distribution on 'tight-coated' sheets (0·57% Sn) and on ordinary sheets (0·24% Sn) has been compared. The sheets were all 24 gauge and were made under similar conditions, except that some were short (60 in.) and others were long (96 in.) in order to see the effect, if any, of extra length. The width was constant at 29½ in. The results for two 60-in. sheets (*E*/1/3 and 7), one of each type, are given in Figs. 16*a* and *b*. Figure 16*a* shows that the results are good, but appreciable face difference is revealed in Fig. 16*b*. The tight-coated sheet has a somewhat thinner coating, 1·25 oz., compared with 1·38 oz., and both nearly satisfy a specification of 'mean — 10%' when face difference is ignored. When interfacial difference is examined (Fig. 16*b*) both sheets narrowly fail to come within — 20% of the mean. However, these results are a distinct improvement on those previously described.

Two longer sheets (*E*/1/1 and 5), again one of each type, have also been examined. The results might be expected to extend over a wider range, but, as shown in Fig. 17, they are strikingly similar to those of the shorter sheets. Interfacial difference again spoils what would otherwise have been remarkably good results. Longitudinal and transverse variation are both slight.

This marked improvement in results is no doubt due to a difference in galvanizing practice. This question will be discussed when all the results have been described and it is merely stated here that at

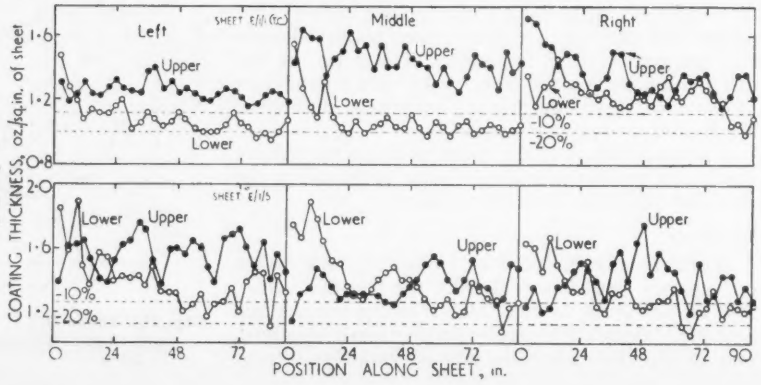


Fig. 17—Sheets *E*/1/1 and 5. Interfacial difference. Sheet 1, 'tight-coated'; sheet 5, ordinary coating. Broken lines indicate the sheet average — 10% and — 20%

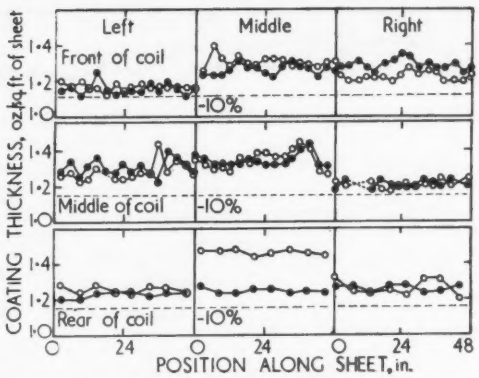


Fig. 18—Sheet *F*/1, front, middle, and rear of coil. Interfacial difference (faces chosen arbitrarily). Broken lines indicate the sheet average — 10%. Coil width 36 in., 23/24 gauge

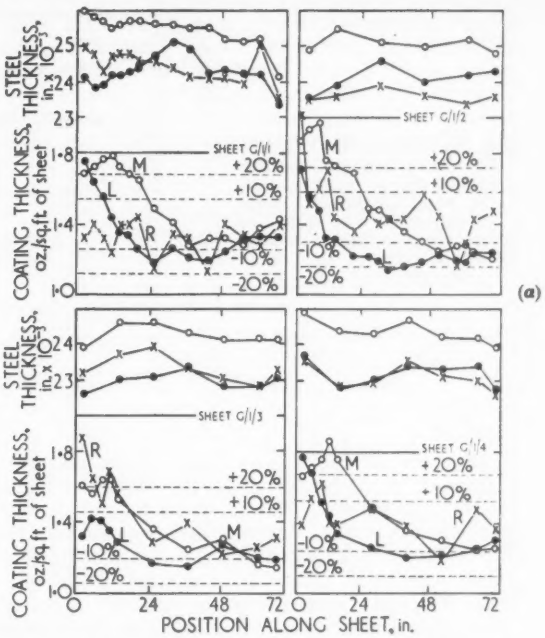
works *E* the pots are smaller and the sheet speed is lower. There are no bottom rolls and, whilst it is difficult to see the effect of this, apart from its indirect effect on speed, it is a variable to be noted. The method of heating is also different.

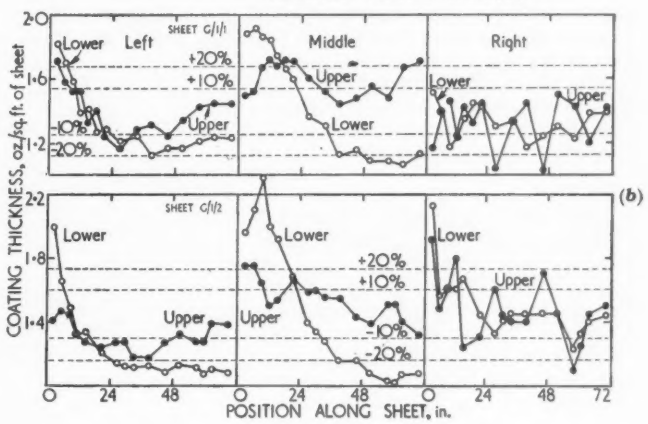
Works *F*

At works *F* coils of cold-reduced steel are continuously galvanized by the Sendzimir process. Samples taken from the front, middle, and rear of a coil 36 in. wide have been examined. The samples were 48 in. long and 24 gauge. Figure 18 shows that the coating is remarkably uniform. (The true upper and lower faces were not known and were chosen arbitrarily.) There is a constant interfacial difference at the middle of the rear sample. The means for the three samples were : front 1·24 oz., middle 1·28 oz., and rear 1·29 oz., so that the whole of a coil would appear to be uniformly coated.

All the results are within ± 10% of the means—a highly satisfactory result.

Spot tests on samples examined on other occasions have confirmed that this process yields a uniformly coated product. Although the process differs in many important respects, the coating is applied by passing the strip into molten zinc and out between exit rolls. This suggests that the process of coating steel with a film of molten metal may be brought under remarkably close control when circumstances are favourable.





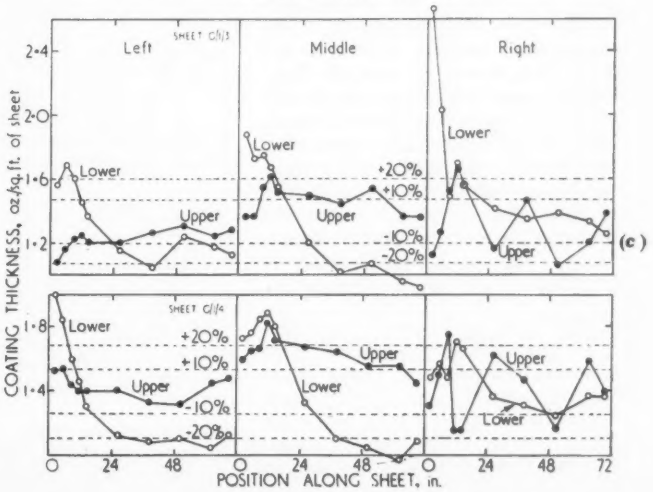


Fig. 19*a*—Sheets *G*/1/1, 2, 3, and 4. Variation of coating (both faces together) and of steel thickness. Broken lines indicate the sheet average ± 10% and ± 20%

Fig. 19*b*—Sheets *G*/1/1 and 2. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

Fig. 19*c*—Sheets *G*/1/3 and 4. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

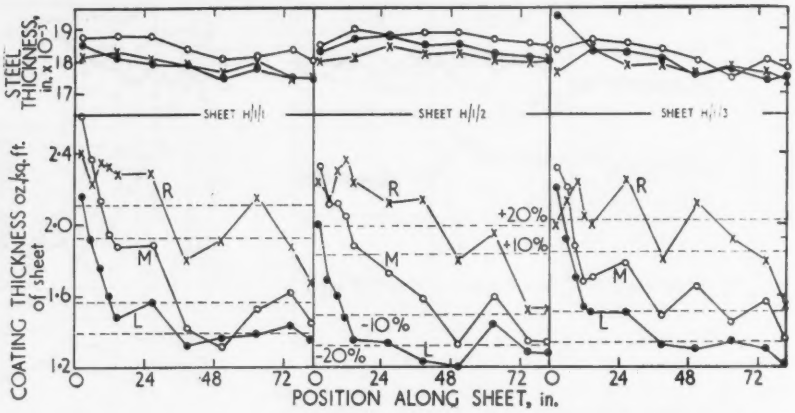


Fig. 20*a*—Sheets *H*/1/1, 2, and 3. Variation of coating (both faces together) and of steel thickness. Note transverse variation of coating thickness. Broken lines indicate the sheet average ± 10% and ± 20%

Works *G*

At works *G* the orthodox galvanizing process is employed, as at works *A* to *E*. Results for four consecutive sheets (*G*/1/1 to 4), 6 ft. × 3 ft. × 24 gauge, are shown in Fig. 19*a*, which gives the variation of the steel thickness and of the zinc coating (both faces together). Interfacial variation is shown in Figs. 19*b* and *c* and is rather pronounced, especially along the central strips; the resemblance between these is very marked. This interfacial difference causes all four sheets to be more than 20% below the mean coating for the sheet, usually on a lower face and for relatively short distances. There is also appreciable longitudinal variation, due to excess coating at the front.

Works *H*

The three sheets from works *H* (*H*/1/1 to 3), 7 ft. × 3 ft. × 26/27 gauge, are of particular interest. They show marked transverse variation with a definite resemblance between them (Fig. 20*a*). The curves for coating variation on each sheet change in character from left to right as the coating increases, and this change is remarkably similar on all three sheets. The resemblance between the three left strips (Fig. 20*b*) is particularly striking and these three strips are remarkably free from interfacial difference. There is an appreciable amount of longitudinal variation and all three sheets are outside the limits ± 20% of the sheet average. (*See* the broken lines in Fig. 20*a*.) This is clearly due to a combination of longitudinal and transverse variation.

Works *I*

The galvanizing practice at works *I* resembled that at works *E* in several respects, *viz.*, lower sheet speed due to smaller pots, and coke-firing instead of the more usual gas or oil. Fundamentally, the process is conducted as in all the other works except *F*, but the results show a definite superiority (works *E* had previously shown the best results).

Two sheets (*I*/1/1 and 2), 6 ft. × 3 ft. × 24 gauge, were provided and were very similar both in total coating, 1·61 and 1·63 oz./sq. ft., and in coating distribution (Figs. 21*a* and *b*). The customary increased coating at the front end is entirely absent, transverse variation is slight and, except on the left of sheet *I*/1/1, interfacial difference is low. These good results are achieved despite the fairly heavy

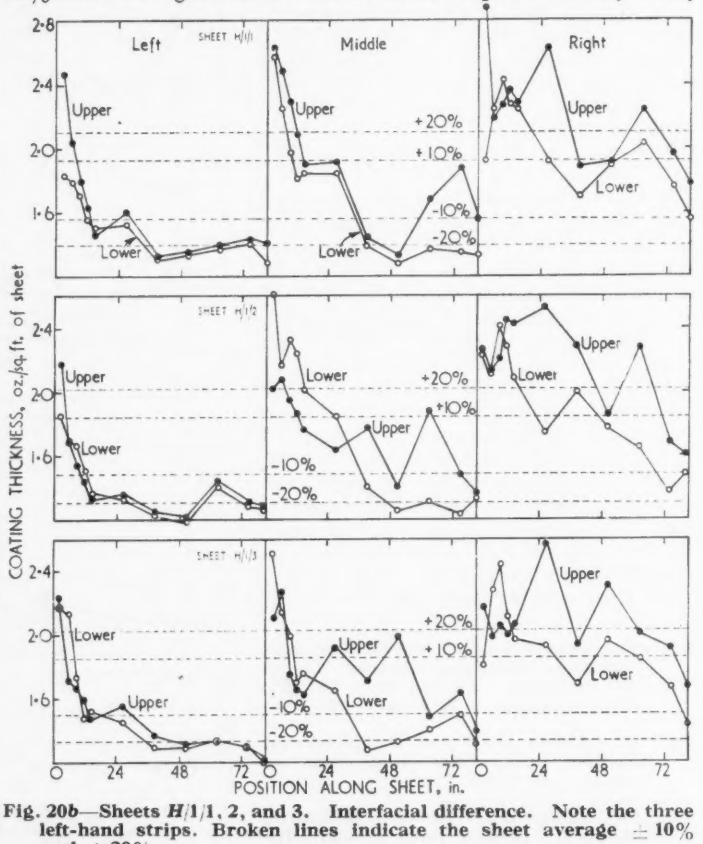


Fig. 20*b*—Sheets *H*/1/1, 2, and 3. Interfacial difference. Note the three left-hand strips. Broken lines indicate the sheet average ± 10% and ± 20%

coating applied ; thicker coatings generally tend to show erratic variations. The steel thickness varies over a wide range (Fig. 21*a*) and, as usual, the middles of the sheets are appreciably thicker, but this wide variation does not appear to have had much effect upon the results.

When both faces are considered together, the coating on both sheets is very nearly within ± 10% of the sheet average but, even when face difference is allowed for, the results come within the limits of ± 20%. Quite a large proportion of the results are still above the ± 10% limits.

In view of these good results two more sheets (*I*/2/1 and 2) were obtained from works *I* about two months later. These were similar in size and gauge, but the coating thicknesses were less, 1·25 and 1·41 oz./sq. ft. The fact that the two coatings differed so much in thickness would, from experience with other samples, be strong evidence that these sheets were not coated consecutively. The results are given in Figs. 22*a* and *b* and are somewhat inferior to those of the first pair. There is here some tendency to show the usual decrease towards the rear. Transverse and interfacial differences are low, the latter being erratic in character.

In addition to its resemblance to that of works *E*, the practice at works *I* is unique in the use of exit rolls with no grooves. Considerable importance is usually attached to the grooves and it is remarkable that instead of producing sheets with an undesirably thin coating, especially along the centre, the coating is fairly thick (1·6 oz./sq. ft.) and has greater uniformity than has been observed elsewhere.

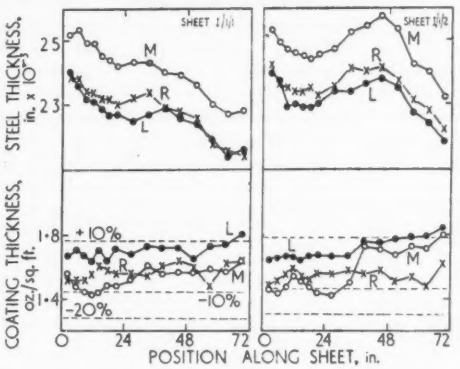


Fig. 21*a*—Sheets *I*/1/1 and 2. Variation of coating thickness (both faces together) and of steel thickness. Broken lines indicate the sheet average ± 10% and ± 20%

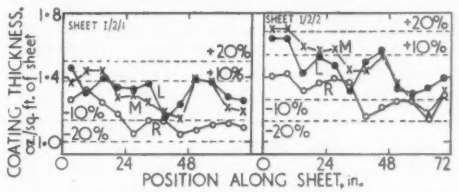


Fig. 22*a*—Sheets *I*/2/1 and 2. Variation of coating thickness (both faces together). Broken lines indicate the sheet average ± 10% and ± 20%

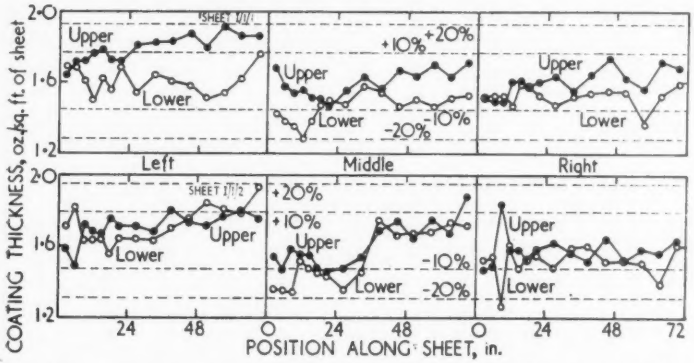


Fig. 21*b*—Sheets *I*/1/1 and 2. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

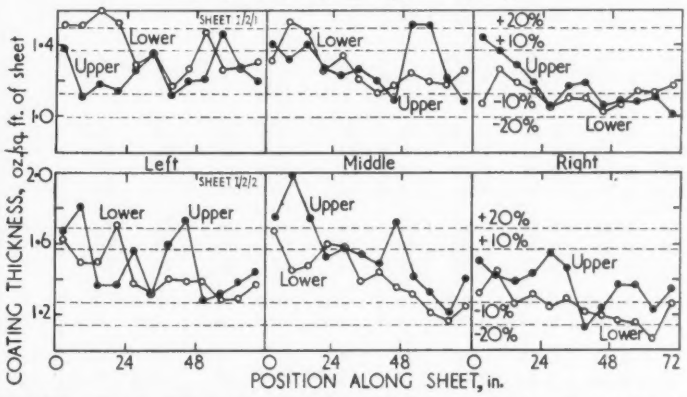


Fig. 22*b*—Sheets *I*/2/1 and 2. Interfacial difference. Broken lines indicate the sheet average ± 10% and ± 20%

METHODS OF ASSESSING RESULTS

The graphs showing the form, location, and extent of the zinc-coating variation on galvanized sheets are not convenient for comparing the degree of variability of the coating on the sheets in a batch or on sheets from several works, nor for relating the variability to changes in the galvanizing process. Something more concise is needed, such as a single numerical quantity to indicate each of the three types of variation. Such a numerical value can be arrived at for longitudinal variation as follows :

The individual results deviate from the mean values by varying amounts. These individual deviations may be summed and the 'mean deviation' then obtained. The simple mean deviation is not generally used ; instead, the individual deviations are squared, the mean of these is found and its

square root is determined. This value is then a convenient and reliable measure of the variability of the results being considered. It is denoted by s. Since the degree of variation is not independent of the actual coating thickness, it is advisable also to express this measure of coating variation (s) as a percentage of the total coating. We then have a coefficient of coating variation which simplifies comparison of sheets or the measurement of improvements with change of practice. Values for the longitudinal variation on a number of sheets, expressed in this way, are given in Table I.

Table I

LONGITUDINAL COATING VARIATION ON GALVANIZED SHEETS

(U = upper face, L = lower face)

Sheet	Mean Coating Value (Whole Sheet), oz./sq. ft.	Standard Deviation (s)						As Percentage of Coating Weight, i.e., Coefficient of Variation						Mean, %
		Left		Middle		Right		Left		Middle		Right		
		U	L	U	L	U	L	U	L	U	L	U	L	
A/1/1	1·35	0·26	0·18	0·30	0·30	0·43	0·25	20	13	22	22	32	19	21
A/1/2	1·29	0·16	0·14	0·13	0·11	...	...	12	11	10	8·4	...	...	10
A/2/1	1·47	0·023	0·11	...	...	0·40	0·36	1·6	7·8	...	...	27	25	15
A/2/2	1·48	0·22	0·19	0·64	0·37	0·53	0·37	15	13	43	25	36	25	26
A/2/3	1·39	0·20	0·25	0·47	0·22	0·39	0·25	14	18	35	16	28	18	21
A/3/1	2·58	0·29	0·27	0·30	0·54	0·20	0·30	11	11	12	21	7·8	12	13
A/3/2	2·24	0·30	0·21	...	...	...	...	13	9	...	...	...	...	11
A/3/3	2·33	0·18	0·17	0·33	0·10	0·41	0·44	8	7·3	14	4·1	18	19	12
A/3/4	1·55	...	...	0·16	0·15	0·23	0·25	...	...	11	9·7	15	17	13
A/4/1	1·64	0·26	0·22	0·31	0·28	0·23	0·30	16	13	19	17	14	18	16
A/4/2	1·58	0·24	0·27	0·31	0·36	0·10	0·58	15	17	20	23	6·3	37	20
A/4/3	1·50	0·37	0·14	0·35	0·17	0·12	0·30	25	9·3	24	12	7·7	20	16
A/4/4	1·50	0·22	0·14	0·14	0·07	0·06	0·12	14	9·3	9·3	4·6	4·0	7·7	8
A/4/5	1·73	0·43	0·22	0·48	0·35	0·30	0·27	25	13	28	20	17	16	20
A/4/6	1·80	0·37	0·25	0·46	0·08	0·33	0·16	20	14	26	4·6	18	8·6	16
B/1/1	1·60	0·14	0·19	0·16	0·20	0·14	0·17	8·8	12	9·7	12	8·8	11	11
B/1/2	1·46	0·17	0·17	...	...	...	...	12	12	One strip only				
C/1/1	1·43	...	...	0·12	0·15	0·10	0·14	...	...	8·6	10	6·9	9·7	9
C/2/0	1·16	0·14	0·14	0·13	0·06	0·17	0·04	11	12	11	5·4	15	3·5	10
C/2/1	1·12	0·09	0·11	0·21	0·11	0·16	0·11	8·2	10	19	9·7	14	9·4	12
C/2/2	1·21	0·12	0·10	0·20	0·16	0·19	0·21	9·5	8·1	16	13	16	18	14
C/2/3	1·14	0·12	0·13	0·25	0·25	0·18	0·10	11	12	22	22	14	8·5	15
D/1/1*b*	1·38	0·20	0·18	0·13	0·21	0·14	0·18	14	13	9·8	15	10	13	13
D/2/1	1·40	0·36	0·25	0·13	0·21	0·23	0·40	26	18	9	14	16	28	11
E/1/1*	1·25	0·06	0·12	0·11	0·12	0·14	0·10	4·4	9·6	8·5	9·8	11·5	8·0	9
E/1/3*	1·25	0·08	0·09	0·09	0·13	0·08	0·13	6·1	7·3	7·3	11	6·0	10	8
E/1/5	1·41	0·11	0·17	0·10	0·19	0·14	0·15	8·0	12	7·0	14	10	11	10
E/1/7	1·39	0·14	0·25	0·10	0·28	0·12	0·20	10	18	7·4	20	8·5	15	13
F/1/front	1·23	0·034	0·020	0·03	0·03	0·03	0·024	2·8	1·6	2·4	2·5	2·5	2·0	3
F/1/middle	1·28	0·048	0·058	0·039	0·052	0·023	0·022	3·8	4·5	3·1	4·1	1·8	1·7	3
F/1/rear	1·29	0·017	0·019	0·036	0·016	0·016	0·049	1·3	1·5	2·8	1·2	1·2	3·8	2
G/1/1	1·40	0·15	0·21	0·10	0·32	0·17	0·034	11	15	7·1	23	12	2·4	15
G/1/2	1·44	0·088	0·26	0·13	0·43	0·21	0·23	6·6	20	9·3	32	16	13	16
G/1/3	1·33	0·024	0·18	0·025	0·36	0·19	0·49	1·8	13	1·9	27	15	37	16
G/1/4	1·39	0·025	0·15	0·028	0·34	0·19	0·14	1·8	11	2·0	25	13	10	11
H/1/1	1·75	0·38	0·18	0·40	0·45	0·39	0·21	22	10	23	26	23	12	19
H/1/2	1·66	0·31	0·21	0·24	0·49	0·35	0·30	19	13	14	30	21	18	19
H/1/3	1·68	0·33	0·31	0·26	0·41	0·27	0·19	19	19	15	25	16	11	18
I/1/1	1·61	0·071	0·069	0·077	0·065	0·071	0·058	4·4	4·3	4·8	4·0	4·4	3·6	4
I/1/2	1·63	0·063	0·098	0·12	0·16	0·092	0·098	3·9	6·0	7·5	9·9	5·6	6·0	7
I/2/1	1·25	0·28	0·14	0·14	0·12	0·13	0·075	23	11	11	9·8	11	6·0	12
I/2/2	1·41	0·18	0·13	0·22	0·16	0·12	0·096	13	9·3	15	11	8·3	6·8	11

* 'Tight-Coated' sheets

Table II

SHEET *A*/1/1 : COMPARISON OF AVERAGE COATING ON FRONT THIRD WITH THAT ON REAR TWO-THIRDS OF SHEET

(U = upper face, L = lower face)

	Mean Coating Values, oz./sq. ft.							
	Left Strip		Left-Centre Strip		Right-Centre Strip		Right Strip	
	U	L	U	L	U	L	U	L
Front third	1·75	1·20	1·97	1·54	1·87	1·60	1·65	1·42
Middle third	1·34	0·91	1·50	1·17	1·45	1·19	1·12	0·99
Rear third	1·52	0·97	1·42	0·99	1·40	1·02	1·09	0·94

For comparison, values have been worked out for longitudinal variation on three sample sheets from works *F*, *i.e.*, strip galvanized by the Sendzimir process. These values are appreciably lower.

The figures for sheets from works *A* demonstrate the persistence referred to earlier. The sheets in group 2 were obtained about two years after those in group 1, whilst group 3 was obtained after a further considerable period. The sheets of group 4 were then obtained about a year later.

It must be remembered that these *coefficients of variation*, given as percentages, do not necessarily indicate longitudinal irregularity along the whole length of a strip. For example, the high value for *A*/1/1 is mainly derived from the front part where the coating thickness is diminishing rapidly. If the strips concerned are divided into front, middle, and rear thirds, the mean coating values in ounces per square foot are as in Table II. From these figures and from Fig. 2*a* it is clear that the longitudinal coefficients of variation would be considerably reduced if only the rear two-thirds of the sheet were considered. The same applies to the other sheets of groups *A*/1 and *A*/2 and to a less extent to group *C*/2.

The efficiency of the coating process is not completely indicated by Table I alone ; a sheet may show very little longitudinal variation, but there may be considerable interfacial or transverse difference.

Interfacial Difference

The interfacial difference has been assessed in a different way. In Table III mean coating values are

Table III

INTERFACIAL COATING VARIATION ON GALVANIZED SHEETS

Sheet	Whole Sheet Average, oz./sq. ft.				Strip Averages (oz./sq. ft.): Lower Face Relative to Upper Face		
	Both Faces	Upper Face	Lower Face	Difference	Left	Middle	Right
***A*/1/1**	1·31	1·48	1·14	−0·34	−0·51	−0·35	−0·17
***A*/2/2**	1·48	1·66	1·31	−0·35	−0·34	−0·37	−0·35
***A*/2/3**	1·39	1·55	1·23	−0·32	−0·31	−0·24	−0·40
***A*/3/1**	2·58	2·60	2·56	−0·04	−0·31	+0·16	+0·02
***A*/3/3**	2·28	3·00	1·67	−1·33	−0·96	−1·30	−1·73
***C*/2/0**	1·16	1·14	1·18	+0·04	+0·09	+0·07	−0·05
***C*/2/1**	1·12	1·15	1·09	−0·06	−0·06	+0·01	−0·12
***C*/2/2**	1·21	1·17	1·25	+0·08	+0·09	+0·16	−0·02
***C*/2/3**	1·14	1·16	1·12	−0·04	+0·02	−0·01	−0·12
E*/1/1	1·25	1·36	1·14	−0·22	−0·11	−0·40	−0·15
E*/1/3	1·25	1·33	1·16	−0·17	−0·23	−0·19	−0·09
***E*/1/5**	1·41	1·46	1·37	−0·09	−0·16	+0·02	−0·12
***E*/1/7**	1·39	1·31	1·46	+0·15	+0·17	+0·26	+0·04
***H*/1/1**	1·75	1·85	1·65	−0·20	−0·15	−0·17	−0·32
***H*/1/2**	1·66	1·73	1·59	−0·14	−0·06	−0·04	−0·33
***H*/1/3**	1·68	1·76	1·61	−0·15	−0·03	−0·14	−0·30
***I*/1/1**	1·61	1·68	1·54	−0·14	−0·18	−0·13	−0·10
***I*/1/2**	1·63	1·65	1·59	−0·06	+0·01	−0·08	−0·09
***I*/2/1**	1·25	1·24	1·27	+0·03	+0·14	−0·01	−0·05
***I*/2/2**	1·41	1·47	1·36	−0·11	−0·06	−0·15	−0·13
***F*/1/front**	1·24	1·23	1·23	Nil	+0·01	+0·05	−0·06
***F*/1/middle**	1·285	1·285	1·285	Nil	Nil	Nil	Nil
***F*/1/rear**	1·29	1·25	1·32	+0·07	+0·21	+0·21	−0·01

*"Tight-Coated" sheets

Table IV

TRANSVERSE VARIATION

(U = upper face, L = lower face)

Distance from Front, ft.	Transverse Mean		Av. Diff. between Separate Tests and Mean (Mean Deviation)	
	U	L	U	L
	Sheet *H*/1/1 (Three Tests)			
(Front)	2·66	2·11	0·15	0·31
1	1·88	1·86	0·28	0·26
2	2·05	1·76	0·39	0·16
3	1·55	1·46	0·23	0·16
4	1·53	1·51	0·25	0·26
5	1·78	1·58	0·32	0·30
6	1·76	1·50	0·22	0·17
	Sheet *A*/1/1 (Four Tests)			
(Front)	1·68	1·89	0·32	0·30
1	1·97	1·45	0·16	0·15
2	1·45	1·13	0·125	0·09
3	1·34	1·11	0·17	0·16
4	1·32	0·97	0·16	0·10
5	1·42	1·015	0·16	0·045
6	1·18	0·93	0·08	0·005
	Sheet *I*/1/1 (Three Tests)			
(Front)	1·62	1·54	0·067	0·097
1	1·63	1·53	0·097	0·103
2	1·67	1·50	0·097	0·027
3	1·68	1·57	0·10	0·03
4	1·68	1·52	0·07	0·02
5	1·74	1·55	0·083	0·043

given for each face of a sheet, together with the difference between them. A minus sign means that the lower face is lower by that amount, and *vice versa*. Similarly, the difference between the two faces of each strip examined is included. Results are given for 20 sheets from five works and, in addition, comparison results are quoted for three sheets from a coil continuously galvanized by the Sendzimir process (works *F*).

Three points arise from an inspection of the figures :

(*a*) Some sheets have considerably less zinc on the whole of the lower face ; for example, of the order of 20% of the mean for the whole sheet (sheet *A*/3/3 is much worse, but is regarded as exceptional). An explanation is needed for this actual deficiency on the lower face. (*See* sheets *A*/1/1, *A*/2/3, *A*/3/3, *E*/1/1, *E*/1/3, and *H*/1/1 in Table III.)

(*b*) The lower-face deficiency is sometimes limited to one strip, and the two faces of the sheet actually carry almost the same amount of zinc. Only in four cases out of 20 is there actually more on the lower side, and in three of these the difference is very small.

(*c*) The good results for works *C* suggest that this very prevalent tendency towards a thinner coating on the lower face is not an inevitable result of hot-dip galvanizing. Taking the four sheets together, the amount of zinc on the lower faces averages 0·005 oz./sq. ft. less than on the upper faces—a negligible amount.

The results for works *F* also show that the hot-dipping principle can be applied with very little variation of the coating thickness.

Transverse Variation

An accurate measure of transverse variation is not possible from the results at present available. In most cases only three tests were made across the sheet at any given distance from the front or leading end. Obviously the values obtained for the transverse mean would differ if more tests were made, except when the change in coating across the sheet is uniform. With this reservation, the results may be used to show that the degree of transverse variation varies appreciably from works to works. This has already been shown by means of graphs, but three examples are now taken for numerical comparison.

The values across the sheet at 1-ft. intervals are averaged, taking the two faces separately. The differences between the individual results and their mean are then found and averaged. The figure obtained, *i.e.*, the mean deviation, is taken as a measure of transverse variation.

The results are given in Table IV. Obviously the results for sheet *I*/1/1 are better than those for *H*/1/1 and *A*/1/1, both of which have previously been shown to exhibit marked transverse variation. We now have an approximate measure of this. Comparison of the results for the two faces suggests that in all three examples there is rather less transverse variation on the lower face, except for a short distance at the front. (The figures for longitudinal variation also show some suggestion of better results on the lower face.)

Quality Control

These results give some indication of the standards of quality which manufacturers could reasonably hope to maintain. It is reasonable, for instance, to conclude that in one case the standard is too low (works *A*), whilst in another (works *I*) the degree of uniformity of the first samples was perhaps too high to expect it to be maintained at all times. A reasonable standard would be a range with an upper value equal to that of the first samples of works *I*, and a lower value which would include the average qualities examined. Such a range has been indicated on the graphs submitted, *viz.*, an upper-quality limit of — 10% of the sheet average and a lower-quality limit of — 20% of that average. *The coating values which are expected to be within this zone, or above it, are those in which both faces are taken together.* If the separate faces are to be considered, as in the graphs showing interfacial difference, then the lower limit of — 20% could reasonably be lowered further. (Com-

parison may be made here with the coating requirements of the A.S.T.M. specification *A*93.46.) For 1·75- and 1·50-oz. coatings similar to those already considered, the following conditions are laid down :

Ordered Coating Weight, oz./sq. ft.	Minimum Coating by Sheet Test	Minimum Coating by Diagonal Triple Spot Test	Minimum Coating by Single Spot Test
1·75	1·50	1·40	1·20
1·50	1·25	1·15	1·0

The minimum single value is allowed to be 20% below the actual overall value for the sheet in both cases. (No distinction between faces is made anywhere in this specification.)

The sheets from works *E* and *I* pass this — 20% test very easily, and they nearly pass a — 10% test. Those from works *C*, despite some excess coating at the front and along the left edge, all pass the test. The four sheets from works *G* all satisfy, but the two sheets from works *D* and the three from works *H* fail, largely because of excessive transverse variation which unduly raises the mean value. It should be noted that the ' minimum coating by single spot test ' would not necessarily have detected these failures, the poor areas being at the rear centre in the *D* samples and at the left rear in the *H* samples. The results obtained at works *A* are generally below this standard.

SUMMARY OF THE RESULTS

The oversheet average remains surprisingly constant from sheet to sheet even when coating distribution is most erratic. Three consecutive sheets showing marked longitudinal, transverse, and interfacial variations had sheet averages of 1·47, 1·48, and 1·39 oz./sq. ft. of sheet. Other groups gave 1·16, 1·12, 1·21, and 1·14 oz./sq. ft. and, to take a heavier coating, 1·75, 1·66, and 1·68 oz./sq. ft.

The works practice of checking the results by weighing sheets before and after galvanizing may thus lead to a false sense of uniformity.

Longitudinal coating variation differs considerably from works to works. It occurs in two forms : a steady fall in value from the front towards the rear, which is usually limited to the front third of the sheet, and also an erratic fluctuation of the coating value, usually with heavier coatings. Only in one case (works *I*, group 1) could the front excess be said to be absent (works *F* is not considered here), although sheets from works *E* showed only a small initial decrease and that over a short distance. The fact that ordinary hot-dipping methods can produce sheets showing little or none of this particular form of maldistribution is a hopeful sign. It is significant that in all such cases the sheet speed is relatively low.

Transverse variation has not been studied in such detail ; only three samples have usually been taken across the sheet at any given position, *viz.*, the two edges and the middle. In two cases, works *A* and *H*, marked transverse variation has been encountered, a drift in coating value from one side to the other being seen. In the case of works *A*, groups 1 and 2, the transverse variation tended to diminish towards the rear of the sheet. It is suggested that the marked transverse variation in these cases may be due to faults in operating the machine.

Interfacial Variation—This form of maldistribution, like the longitudinal type, has certain recurring features. The general tendency is for the lower face to be poorer in zinc, often by a considerable amount. It is of very frequent occurrence. Sheets have been examined, however, in which the face difference is considerably lower than usual (works *C*). In another case (works *H*) three sheets showed very little face difference indeed along the left strips. These facts suggest that conditions can be found under which interfacial difference may be considerably reduced.

The question arises here whether interfacial difference could be a result of transverse variation and not a separate phenomenon. If it were possible for the coating on the upper face of a sheet to be partially moved from left to right it would mean (*a*) transverse variation, increasing to the right ; (*b*) a reduction or elimination of the usual lower-face deficiency on the left, or even an excess on the lower face, according to the extent of the coating transfer ; and (*c*) a corresponding increase in the lower-face deficiency found on the right.

The three sheets in works *H*, group 1, show marked transverse variation, and the three effects (*a*), (*b*), and (*c*) are, at first sight, contained in these results. They cannot be taken as an example of the above hypothetical condition because the transverse variation occurs also on the lower face on all three sheets ; the values for the lower faces of the left, middle, and right strips of these three sheets are :

(1) *L* 1·44, *M* 1·62, *R* 1·88
(2) *L* 1·36, *M* 1·62, *R* 1·78
(3) *L* 1·45, *M* 1·59, *R* 1·78

Also the very close agreement of upper and lower faces on the left on all three sheets cannot be fortuitous.

The possibility remains that one variation may be reflected in another and this complicates the question of assessing the value of the sheet as a whole from the point of view of distribution.

Persistence of Coating-Variation Results

On more than one occasion the distribution results obtained at a given works were similar for samples taken at considerable intervals of time. If this can be shown to be generally true, then some light may be thrown on the question of the factors causing such variations. Certain variables would appear to be considerably reduced in significance, *e.g.*, day-to-day variations in steel composition, pickling conditions, etc. The remarkable similarity between the results for a group of three or four sheets also suggests that the causes of coating variation are to be found in the galvanizing process itself, rather than in the steel base or its preparation.

The present results, and the conclusions based on them, represent mainly orthodox galvanizing practice employing pack-rolled sheets made by conventional methods. A change from pack-rolled to cold-reduced sheets might have an appreciable effect on the results at any given works. A comparison of the two materials under the same galvanizing conditions should yield interesting results, and arrangements have already been made to carry out such an experiment.

INFLUENCE OF GALVANIZING TECHNIQUE ON THE DISTRIBUTION OF COATING THICKNESS

It has not been possible in the course of this survey to establish any firm connection between the results obtained from individual works and the galvanizing practice employed there. It was decided some time ago that a proper assessment of the influence of galvanizing practice on coating quality could be made only under carefully controlled conditions of experiment. A pilot-scale galvanizing machine has been made at the author's laboratories for this purpose and has already produced some interesting and significant results. In the meantime the factors which appear likely to influence the distribution of coating thickness have been considered and are discussed below.

In the type of galvanizing process which forms the subject of this study, steel sheets, previously pickled and washed, first pass downwards through a layer of flux floating on the molten zinc in the galvanizing bath. From here they are led, by means of guides and driven rolls, through the main body of the metal in a semi-circular path ; they then emerge vertically between a pair of rolls running in the surface of the zinc at the exit end of the bath.

During its passage through the molten zinc, the sheet, cleaned by passing through the flux, acquires a layer of solid iron–zinc alloy on its surface. When the sheet leaves the bath it carries with it a coating of molten metal which varies in thickness according to the operating conditions.

FACTORS DETERMINING OVERALL COATING THICKNESS

The final overall coating thickness may vary owing to variation in the thickness of alloy layers formed or of the outer layer of molten metal withdrawn on the sheet, or to variation in both. It is believed that in sheet galvanizing the factors controlling alloy thickness are almost constant in any particular works, and interest is therefore concentrated on the film of molten zinc drawn out by the sheet. The factors which may affect this are :

(1) The level of the molten zinc surface relative to the ' nip ' of the exit rolls. To increase coating weight the zinc level is raised a fraction of an inch above the nip by making additions of zinc to the bath.

(2) The speed of the sheet. An increase in speed increases coating weight[7] ; this increase in coating is more pronounced at the front of the sheet than elsewhere.

(3) The temperature of the bath. An increase in temperature reduces the viscosity of the bath and, hence, the amount of zinc drawn out.

(4) The composition of the bath.[6] Additions of tin or aluminium to the bath increase its fluidity, either by reducing the viscosity of zinc or, as is thought in the industry, by some kind of cleansing action. (These additions also widen the freezing range of the molten metal.) The effect is to reduce the coating thickness. An additional factor arises in the case of aluminium. If sufficient aluminium is added to prevent alloy formation, then, obviously, the total coating thickness will be less by that amount. This makes an appreciable difference since alloy frequently amounts to 50% or more of the coating thickness.

(5) The pressure on the exit rolls. An increase in pressure decreases coating thickness, although this appears not to apply when the zinc is above the nip.

(6) The grooving of the exit rolls. These grooves are intended to maintain a supply of zinc to the roll–sheet interface to replace that taken away by the emerging sheet. They vary in size, number, and arrangement on the roll, and there appears to be considerable difference of opinion in the industry as to the best arrangement, although, except in one works, it is generally agreed that they are essential and that they must be cleaned regularly.

For coating-control purposes factor (1), *i.e.*, the level of the molten zinc, is chosen. This can be varied with little trouble at relatively short notice ; this is obviously not the case with (3), (4), and (5). Variable (2) is used to compensate for variation in sheet gauge, speed being diminished with extra thickness for thermal reasons.

No instrument appears to be available for measuring the variation in metal level within the nip. It is usually controlled on a basis of trial and error, the operators being able to estimate by inspection the results being obtained, which are confirmed by laboratory tests or ' sheet tests.' The level *outside* the nip is a sufficient guide for most purposes.

SOURCES OF VARIATION IN COATING THICKNESS

From the foregoing discussion of the factors affecting coating thickness, it would appear that the chief sources of coating variation are the conditions at the exit rolls. The alloy layers are solid when they reach these rolls and are not affected, except, perhaps, to be consolidated a little. In any case, variation in speed (*i.e.*, time) and temperature, such as to cause a change in the amount of alloy, should affect the whole sheet equally and should not be a serious cause of coating variation over a sheet. A possible exception is the existence in the bath of wide temperature gradients *across* the pot leading to transverse variation in the amount of alloy. This possibility has been examined at two works, with pyrometers, but no evidence of appreciable temperature difference has been found. The necessity to safeguard the life of the pot leads to vigilance in this matter of local overheating.

The following discussion of possible sources of variation in the outer layer of zinc is intended as a basis upon which practical tests can be carried out.

Longitudinal Variation

If the zinc level is *slightly* above the nip of the exit rolls, corresponding to a given coating thickness, then the following would explain a fall in coating towards the rear.

The first part of the sheet carries away with it some of the liquid zinc above the nip, to an extent largely dependent upon sheet speed. Unless the supply of zinc is renewed, the level will fall slightly, and the coating on the sheet will get thinner. At first sight it would appear that zinc should flow in from other parts of the bath, but owing to the lack of easy access to the nip, there seems to be some lag. The grooves in the roll are intended to supply zinc, especially to the centre portion where the sheet is thickest and the squeezing action of the rolls is most pronounced. If these grooves bring in sufficient zinc there does not seem to be any reason why coating thickness should diminish to the rear ; with thick coatings it should even increase to the rear as the result of drainage.

A study of the results obtained in the various works suggests that an equilibrium is soon set up between the amount of zinc taken from the nip by the sheet and the amount brought in by the grooves or by other paths. The coating thickness becomes more uniform at a short distance from the front ; this distance varies in different cases and, of course, during the short interval between the passage of two sheets the original conditions are restored and the process is repeated. In the extreme case when strip is continuously galvanized, an unbroken equilibrium between the zinc taken out and that brought into the nip by the grooved rolls is possible, and the coating on such strip is very uniform.

There is, however, so little evidence available regarding zinc levels in the nip that this explanation must be regarded as purely tentative. When heavier coatings are aimed at and there is appreciable zinc above the nip, the foregoing discussion does not apply.

In one of the works visited exit rolls without grooves are used. In addition, at this works it is not considered necessary to have the zinc level above the nip. These two conditions both tend to reduce the amount of metal available to the sheet at the nip, and sheets from this works were remarkable for the absence of extra coating thickness at the front.

It has already been pointed out that longitudinal variation is least in those works (*E*, *F*, and *I*) which operate at relatively low sheet speeds.

Transverse Variation

Two operational causes of transverse variation are suggested :

(1) Failure to set the rig so that the exit rolls are horizontal. Any difference in level will mean that the zinc will be higher in the nip on one side than on the other.

(2) There is some evidence that the side of the sheet nearer the drive is liable to carry a heavier coating. This could be due to failure to tighten up the exit rolls on that side possibly because of the slightly greater difficulty in reaching this position, owing to the drive. Operators are often warned to keep away from the drive, which may lead to neglect of adjustments on that side. It is significant that in two works the excess coating is on the left and so is the drive, whilst in a third the excess coating and the drive are both on the right.

A number of curves are given in this paper which show that pack-rolled sheets are appreciably thicker at the centre than at the edges ; the difference amounts to 0·001–0·002 in. There is thus a tendency for the exit rolls to press tightly on the central portion of the sheet, but to leave a certain amount of freedom at the edges. This would be expected to produce a thinner coating at the centre. The results do not entirely confirm this, possibly because of the simultaneous operation of other factors. In some works the grooves are more closely spaced at the centre in anticipation of this effect. However, in some cases the thinner coating at the centre is quite pronounced. (*See* Figs. 3, 4*a* (rear), and 15.)

Interfacial Coating Difference

The chief difficulty here is to explain the tendency to a smaller total coating on the lower side of so many sheets. This is not due to a difference in the amount of alloy ; the chief factors of time and temperature are the same for both faces. A sufficient number of sheets has been examined under the microscope to provide strong evidence that there is not usually any appreciable difference in the amount of alloy on the two faces, but that the variations are in the outer layer only.

The explanation generally proposed by the industry is that the sheet, whilst still between the exit rolls, is made to bend over towards the rear in order to guide it towards the conveyor which takes the sheet away. The sheet then tends to ' flop ' over towards the rear exit roll with the result that its path from the nip upwards is no longer through the middle of the zinc in the nip. It is believed, in fact, that the sheet actually lies on the rear exit roll for a short distance, sufficient to prevent the zinc in the nip from reaching the rear or lower face of the sheet. It may also assist the rear roll to take away with it more fluid zinc than it would otherwise do, at the expense of the coating on the rear face of the sheet.

An examination of the coating results in some cases supports the theory, but contradicts it in others. For instance, it is supported by the fact that in many cases the deficiency on the lower face does not appear on the front portion of the sheet ; in fact the lower face may have a thicker coating for the first 18–24 in. In other cases, there is a marked interfacial difference all along the sheet, beginning with the first sample, which does not agree with the theory. On the other hand, galvanized strip, which is taken up vertically from the exit rolls, shows little difference between the two faces, which tends to support the idea.

It has been observed (*a*) that sheets carrying heavier coatings, *i.e.*, more zinc in the nip, tend to show more interfacial difference, and (*b*) that sheets showing considerable transverse variation reveal the fact that, as the coating increases, interfacial difference increases *on the same sheet*.

It is difficult to decide at this stage just how much weight should be attached to the various pieces of evidence for and against this theory. Other factors have to be borne in mind, such as the ' spring ' of the curved sheet as it enters and leaves the exit rolls in relation to the pressure between its faces and the two rolls.

This discussion will have indicated that much of the existing knowledge of this subject is based on hearsay evidence and opinion, some of it controversial. Controlled experiments under laboratory conditions, but on a practical scale, are urgently required.

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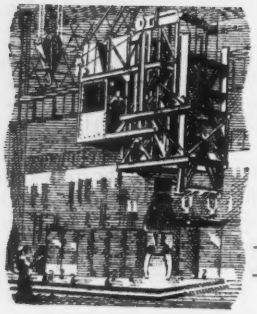

IRON AND STEELWORKS ENGINEERING

THE IRON AND STEEL ENGINEERS GROUP

Trials of an Experimental Austeel-Escher Metallic Recuperator

By J. B. Davis, M.A., A.M.I.Mech.E., W. Ernest, G.I.Mech.E., and H. Kay, M.Sc., M.Inst.F.

SYNOPSIS

A series of trials was carried out on a small Austeel-Escher metallic recuperator to observe its operating characteristics under widely varying conditions. The paper describes the experimental procedure adopted, and refers to some of the more important data obtained.

THE Austeel-Escher recuperator[1] was originally developed in Australia during the early war years, and has been used on a number of furnace installations there. Some information, with a description of this novel type of metallic recuperator, was given in 1947 by Escher.[2,3]

Since the Austeel-Escher recuperator appeared to offer some advantages over many existing types of recuperator, especially in conjunction with soaking pits, it was considered that the construction and testing of a small unit would be justified. Accordingly, a small recuperator was designed by Messrs. Stein and Atkinson, Ltd., for a furnace made available for the tests by Messrs. Steel, Peech and Tozer. The tests of the recuperator were conducted jointly by engineers of Messrs. Stein and Atkinson, Ltd., and of the Research and Development Department of The United Steel Companies, Ltd. Certain tests were planned to simulate, as closely as possible, soaking-pit conditions, and others were to yield data for design purposes under varying operating conditions.

EXPERIMENTAL EQUIPMENT

The tests were carried out on a disused coke-oven-gas-fired forge furnace. In effect, this furnace was used merely as a combustion chamber to produce hot waste gases; since the furnace was not required for production, the waste-gas flow and the temperature could readily be varied as required. It was also arranged to vent the preheated air from the recuperator to atmosphere, rather than to return it to the furnace as combustion air.

The general arrangement of the experimental set-up is shown in Fig. 1. The waste gas leaves the furnace through the port in the endwall and flows through a refractory-lined flue duct, the recuperator, a refractory Venturi, and thence to a short auxiliary stack. The original waste-gas ports in the furnace hearth were covered with loose refractory tiles. These ports in the hearth could be used to by-pass the required proportion of the waste gases. The composition of the waste gas was varied by injecting into the furnace either excess air or water.

The recuperator air was supplied by means of a fan capable of delivering 300 normal cu. ft./min. against a pressure of 18 in. W.G. The air ducting to the recuperator was arranged in a manner such that it could be connected to either end of the recuperator, to enable tests to be carried out in both parallel and counter flow. Figure 1 shows the recuperator connected in parallel flow. The experimental recuperator was nominally designed to preheat, to about 500° C., the air required for the combustion of about 2500 normal cu. ft./hr. of coke-oven gas with waste gas at 1200° C. in parallel flow.

The approximate dimensions of the recuperator were as follows:

Internal diameter (waste-gas passage)	2 ft.
Overall outside diameter	2 ft. 9 in.
Overall length	9 ft.

The recuperator itself was almost entirely constructed of heat-resisting steel. The inner shell was

Manuscript received 22nd August, 1950.

Mr. Davis and Mr. Ernest are in the Research and Development Department of The United Steel Companies, Ltd., Rotherham, and Mr. Kay is on the staff of Messrs. Stein and Atkinson, Ltd., London.

made of a 25/16 Cr–Ni steel; the outer shell was of an 18/8 Cr–Ni steel, with a short section of 25/16 Cr–Ni steel at the end remote from the furnace. At this end the exterior of the recuperator was insulated for parallel flow conditions (*see* Figs. 1 and 2).

The design incorporated two safety devices to prevent overheating of the recuperator:

(i) A section of the recuperator was not insulated, so that heat would be dissipated rapidly in the event of overheating

(ii) Provision was made to dilute with cold air, or, if this proved inadequate, with water, the waste gases entering the recuperator. The cold air and water used for dilution could be admitted into the waste-gas duct between furnace and recuperator, through valves actuated by the thermal expansion of the recuperator through a mechanical linkage.

Instruments and Observations

Most of the points of measurement are shown in the schematic arrangement of the experimental equipment (Fig. 2).

Waste-Gas Temperature—This was measured:

(i) Leaving the furnace
(ii) Entering the recuperator
(iii) At the recuperator outlet and before the Venturi.

The temperatures were measured by means of sheathed platinum–rhodium thermocouples connected to a multi-point indicator. To compensate for errors of reading caused by radiation from the sheath, frequent spot checks were made, using unsheathed thermocouples and also suction pyrometers. The thermocouples were arranged so that the tip of the sheath projected into the centre of the duct.

Temperature of Brickwork in the Ducts Before and After the Recuperator—Measurements were made:

(i) At three points in the connecting flue between furnace and recuperator
(ii) At the entry to the Venturi.

Measurement of the temperature of the brickwork was necessary because radiation from these surfaces plays an appreciable part in the heat transfer to the recuperator partition. Sheathed platinum–rhodium thermocouples were used, mounted flush with the inner brick face.

Waste-Gas Flow through Recuperator—Since it was essential to obtain an accurate measurement of the volume of waste gas flowing through the recuperator under all conditions, a refractory Venturi was constructed, and was positioned immediately after the recuperator. This Venturi was calibrated, by means of cold air, before and after completion of the experiments. Because of the small pressure differential obtained, a micromanometer was utilized for this flow measurement.

Air Flow—The air to be preheated in the recuperator and the air for diluting the waste-gas flow through the recuperator were both measured by means of standard orifice plates in the cold-air supply pipes from the fans.

Air Temperatures—The following were measured:

(i) Ambient temperature
(ii) Temperature on leaving recuperator.

Waste-Gas Composition—The waste gas was analysed for CO_2 by means of an Orsat apparatus, and for H_2O by means of an absorption method employing activated alumina. Considerable importance was attached to the accuracy of these measurements, owing to the importance of non-luminous gaseous radiation in this type of recuperator.

Recuperator Metal Temperatures—These were measured at:

(i) The inner shell at four points
(ii) The outer shell at six points.

These temperatures were measured by means of chromel–alumel thermocouples welded to the respective surfaces. The method of attachment to the inner shell is shown in Fig. 3. All these thermocouples were connected to a 12-point indicator.

Measurements, at points not shown in Fig. 2, included the overall expansion of the recuperator, the air pressure at the fan, the pressure loss through the recuperator, fuel-gas analysis, and an assessment of the heat losses from the exterior of the recuperator by means of temperature-indicating chalks (Tempilstiks). The latter measurement was carried out to provide an approximate check for the heat balance.

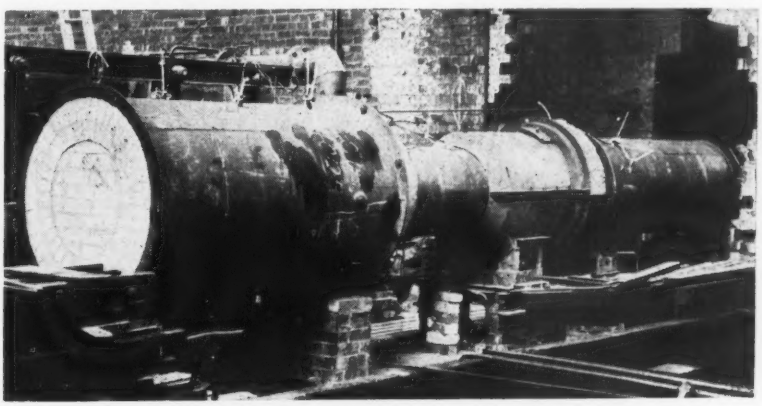

Fig. 1—General arrangement of experimental equipment

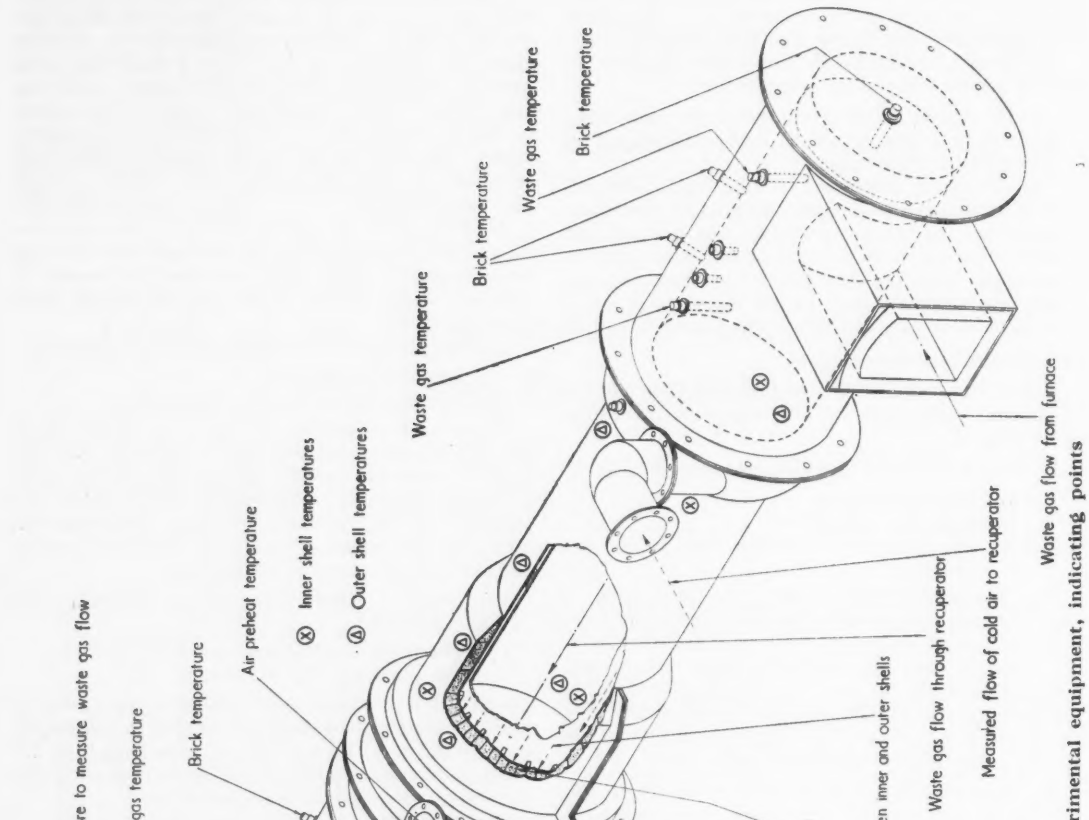

Fig. 2—Schematic view of experimental equipment, indicating points

EXPERIMENTAL PROCEDURE

Fifty individual tests were carried out over a period of five weeks. The tests were designed to vary, as widely as possible, several of the factors which influence the operation of the recuperator, *i.e.*, waste-gas flow, temperature and composition, air flow, and the insulation of the recuperator exterior. Also, the recuperator was tested in parallel flow and counter flow.

While the trials were in progress the furnace was operating continuously. The fuel supply was reduced at night and was increased in the morning to approximately the rate required for the tests, which were carried out in the afternoons. Furnace conditions were maintained steady while the test observations were recorded, and only the recuperator air flow was varied. The duration of each test was nominally 30 min., test readings being recorded when substantially steady conditions had been attained. From two to four test runs were completed each day.

DISCUSSION OF RESULTS

Results which are of more immediate practical significance are summarized in Table I.

Parallel Flow

The results of the tests in parallel flow are of particular interest, because the recuperator was specifically designed for such conditions. Parallel flow would probably be employed when relatively high waste-gas temperatures are encountered.

Tests *D*31, *D*14, *D*18, *D*16, *E*33, and *E*20 are for approximately normal operating conditions; in all these tests the maximum indicated metal temperature was within the safe working limits (about 900° C.) of the steel employed, and an air preheat of over 500° C. was obtained, except for Test *D*31 in which the fuel supply was reduced. For Test *E*20 the waste-gas temperature was considerably higher than that expected for normal soaking-pit conditions, but even so the maximum indicated metal temperature was within safe limits.

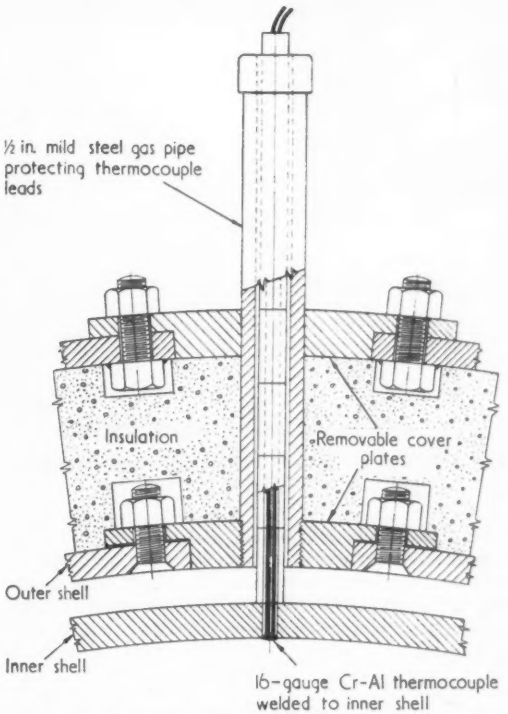
½ in. mild steel gas pipe protecting thermocouple leads
Insulation
Removable cover plates
Outer shell
Inner shell
16-gauge Cr-Al thermocouple welded to inner shell

Fig. 3—Method of attachment of thermocouple to inner shell of recuperator

Table I

SUMMARY OF TEST RESULTS OF EXPERIMENTAL AUSTEEL-ESCHER RECUPERATOR

Test No.	Flow*	Volume of Air Preheated, cu. ft./hr. at N.T.P.	Waste Gas: Flow Through Recuperator, cu. ft./hr. at N.T.P.	Waste Gas: Volumetric Analysis on Wet Basis, CO_2, %	Waste Gas: Volumetric Analysis on Wet Basis, H_2O, %	Fuel-Gas Flow,† cu. ft./hr. at N.T.P.	Temperature, °C.: Waste Gas Leaving Furnace	Temperature, °C.: Ambient	Temperature, °C.: Pre-heated Air	Temperature, °C.: Maximum Indicated Metal Temperature	Operating Conditions
*D*31	P	5410	6070	7·3	19·4	1030	1226	34	486	548	Ratio of volume of preheated air to fuel-gas flow, and other operating conditions, approximately normal
*D*14	P	12,770	15,280	7·7	19·8	2690	1280	31	542	637	
*D*18	P	9560	10,520	7·5	20·9	1810	1288	29	530	633	
*D*16	P	16,120	15,650	7·4	20·0	2660	1306	30	510	573	
*E*33	P	10,750	13,250	7·3	19·1	2220	1308	28	568	682	
*E*20	P	15,380	17,680	7·6	20·4	3080	1408	28	592	732	
C 9	P	11,010	21,820	7·3	22·3	3655	1218	38	628	737	Ratio of preheated air to fuel-gas flow below normal
*D*15	P	9480	15,610	7·5	20·0	2685	1298	33	600	710	
*E*34	P	8000	13,680	7·4	19·0	2320	1336	28	608	733	
G 6	C	11,840	13,480	6·1	16·4	1880	820	30	243	342	Operating conditions approximately normal
*H*39	C	11,460	13,200	7·4	21·8	2240	1083	31	468	622	
*R*43	C	14,350	16,000	6·0	16·4	2200	908	34	310	445	Without } Waste-gas spinners
*P*49	C	13,400	14,990	4·6	13·5	1580	821	35	352	462	With } in recuperator

* P = parallel flow; C = counter flow.
† Calculated from the observed waste-gas composition and the flow through the recuperator.

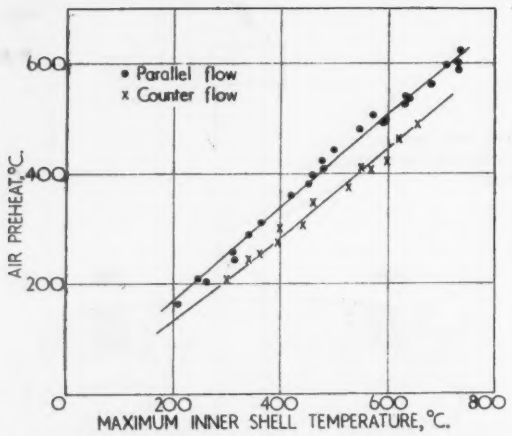

Fig. 4—Air preheat versus maximum metal temperature, for parallel and counter flow

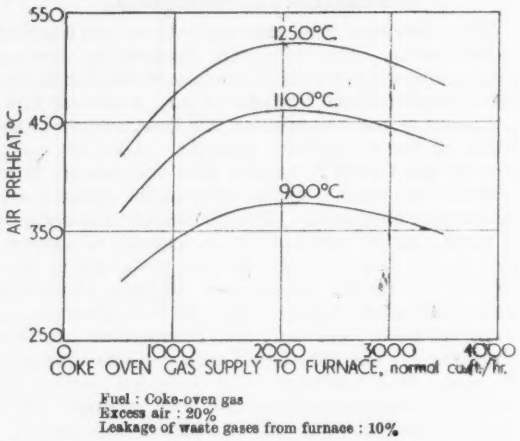

Fig. 5—Characteristic curves for experimental recuperator

For Tests *C*9, *D*15, and *E*34, the flow of air through the recuperator was greatly reduced in relation to the waste-gas flow. In these tests an air preheat of 600° C. or more was obtained, the maximum indicated metal temperature still being within safe working limits.

Counter Flow

This type of recuperator is generally used in counter flow when relatively low waste-gas temperatures are encountered. Although the experimental unit was designed for parallel flow, some tests were made in counter flow. Tests *G*36 and *H*39 are for approximately normal conditions.

In Fig. 4, air preheat has been plotted against maximum indicated metal temperatures, for a number of tests in both parallel and counter flow. For a given air preheat, the metal temperature is lower for parallel than for counter flow, which is a practical demonstration of the necessity for limiting the counter-flow arrangement for use with the lower waste-gas temperatures. Heat transfer by non-luminous, gaseous radiation diminishes with temperature. Accordingly, tests were conducted to investigate the possibility of increasing, at the lower waste-gas temperatures, the heat transfer by convection. Spinners were introduced into the recuperator to promote turbulence in the waste-gas stream, thereby increasing the convective heat transfer. A comparison of Tests *R*43 (without waste-gas spinners) and *P*49 (with waste-gas spinners) suggests that at these somewhat low waste-gas temperatures there is a considerable advantage in using spinners.

Recuperator Expansion

The observed results indicated reasonably good correlation between the axial expansion of the recuperator and both the mean and maximum indicated inner shell temperatures. A rise of 100° C. in the maximum metal temperature caused an extension of $\frac{1}{4}$ in. for parallel flow and $\frac{1}{2}$ in. for counter flow. Recuperator expansion, therefore, can safely be utilized to actuate the safety devices and so prevent overheating.

Condition of Recuperator

At the conclusion of the tests, after operating for approximately 500 hours, the recuperator was examined internally and was found to be in good condition. The appearance of the inner shell suggested that nowhere had the safe working temperature 900° C., been exceeded.

Recuperator Characteristic

Figure 5 shows the characteristic curves of the recuperator, for various waste-gas temperatures, under actual operating conditions and in parallel flow. These curves were calculated by a method which has been verified by the experimental data obtained.

CONCLUSIONS

The results of these tests demonstrate that the principle of the Austeel-Escher recuperator is sound, and that this method of recuperation is suitable for a wide range of operating conditions.

Under conditions simulating those of the soaking-pit (to which special attention was given), the recuperator performance was satisfactory. It is deduced that an Escher recuperator could be designed to operate satisfactorily with a waste-gas temperature greater than 1400° C., and with an air preheat in excess of 600° C.

Acknowledgments

The authors thank the Director of Research, United Steel Companies, Ltd., and the Managing Director of Messrs. Stein and Atkinson, Ltd., for permission to publish this paper.

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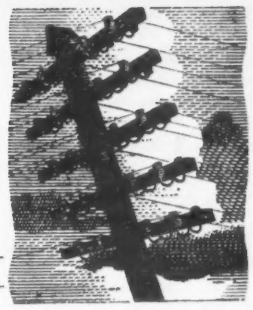
N E W S



ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

President-Elect

Mr. RICHARD MATHER has been nominated by the Council for election as President for the year 1951–52, to take office at the Annual General Meeting in May.

Mr. Mather, who has been a Member since 1913, is a Vice-President of the Institute. He is Chairman and Managing Director of the Skinningrove Iron Co., Ltd.

Meetings

Annual General Meeting, 1951

The Annual General Meeting of the Institute will be held in London from 30th May to 1st June, 1951.

As hotel accommodation in London is limited, Members who intend to take part in the Annual General Meeting are advised to make their own reservations at an early date.

Special Meeting in Austria

The Council have accepted an invitation of the Austrian Iron and Steel Institute (Technisch-wisssenschaftlicher Verein Eisenhütte Öesterreich) to hold a Special Meeting in Austria. The Meeting will be held from about 15th September, 1951, in conjunction with the meeting of the Institute of Metals to be held in Italy from 17th–25th September.

Awards

Bessemer Medal for 1951

The Bessemer Medal for 1951 has been awarded to Mr. Benjamin Fairless, President of the United States Steel Corporation, in recognition of his distinguished services to the iron and steel industry.

Mr. Fairless was born at Pigeon Row, Ohio, in 1890, and was educated at Wooster College and Ohio Northern University, where he graduated in Civil Engineering in 1913. After working for a short period on the construction of the Wheeley and Lake Erie railroad, he joined the Central Steel Company of Massillon, Ohio, and was appointed successively Mill Superintendent, General Superintendent, and Vice-President in Charge of Operations.

In 1931 after holding various other appointments, he became President and Chairman of the Executive Committee of the United States Steel Corporation (Delaware) and later became its Chief Administrative Officer. He is also a Director of the U.S. Steel Corporation of New Jersey. He was appointed to his present position of President of the Corporation in 1938.

During the last war, Mr. Fairless served in an advisory capacity on the staff of the Chief of Ordnance, and as a member of the Iron and Steel Advisory Committee of the War Production Board. For these services he was awarded the Medal for Merit in 1946.

His academic distinctions include a doctorate in engineering of the Stevens Institute of Technology, obtained in 1943, and an honorary degree of Kent State University and of the University of Pittsburgh. Mr. Fairless is also Vice-President of the American Iron and Steel Institute.

Sir Robert Hadfield Medal for 1951

The Sir Robert Hadfield Medal for 1951 has been awarded to Mr. W. Barr, Chief Metallurgist and Executive Director of Colvilles, Ltd., and a Director of Fullwood Foundry Co., Ltd.

He was educated at the Hamilton Academy and at the Royal Technical College, Glasgow, where he gained the Diploma in Metallurgy in 1921 and the Associateship of the College in the following year. After completing his academic training Mr. Barr joined the staff of Messrs. David Colvilles, Ltd., as metallurgist. In the following year he was appointed Assistant Works Metallurgist at the Dalzell Works. After the formation of Colvilles, Ltd., he became Chief Metallurgist of the company in 1936. In 1945 he was appointed a Director of the Fullwood Foundry Company, Ltd., and in 1947 he became Executive Director of Colvilles, Ltd.

Mr. Barr has served on many technical committees. He is a Founder Fellow and Member of Council of the Institution of Metallurgists and has been a Member of Council of The Iron and Steel Institute since 1948. He was elected President of the West of Scotland Iron and Steel Institute in 1949.

Andrew Carnegie Scholarship

Mr. A. RODGERS has been awarded a £250 scholarship by the Andrew Carnegie Trust to carry out work on the investigation of the internal friction of steels, with special reference to grain-boundary phenomena, at Sheffield University.

The Bessemer Medal

In 1873 Sir (then Mr.) Henry Bessemer invested the sum of £400 in perpetual debentures of the London and North-Western Railway, to procure annually a Medal, to be awarded at each of the Annual Meetings of the Institute. The Council may award the Medal to either members or non-members of the Institute. The awards are to be (1) to the inventor or introducer of any important or remarkable invention, either in the mechanical or chemical process employed in the manufacture of iron or steel; (2) for a Paper read before the Institute, and having special merit and importance in connection with iron and steel manufacture; (3) for a contribution to the *Journal* of the Institute, being an original investigation bearing on the iron and steel manufacture, and capable of being productive of valuable practical results. The Council may, in their discretion, award the Medal in any case not coming strictly under

the foregoing definitions, should they consider that the iron or steel trades have been or may be substantially benefited by the person to whom such award has been made.

The Trustees of the Bessemer Medal Fund are :

Desmond Lysaght
The Hon. R. G. Lyttleton
N. H. Rollason

NEWS OF MEMBERS

▶ Mr. J. M. BUTLER has been appointed an investigator at the British Non-Ferrous Metals Research Association.

▶ Mr. P. K. CHATTERJEE has been awarded the B.Met. degree, in Ferrous Metallurgy, of the University of Sheffield and has returned to India to take up an appointment with the Inspectorate of Metal and Steel at Ishapore.

▶ Mr. C. G. CONWAY has left Power Jets (Research and Development), Ltd.

▶ Mr. T. B. CORBETT has left John Williams (Wishaw) Ltd., Excelsior Iron and Steel Works, Wishaw.

▶ Dr. H. E. DAVIES, Chief Metallurgist at The Park Gate Iron and Steel Company, Ltd., has taken up an appointment as Metallurgist to the British Electricity Authority with headquarters in London.

Dr. Davies, who is a native of Neath, South Wales, graduated B.Sc. with First Class Honours in Metallurgy, at University College, Swansea, in 1932. After periods of research, first at Sheffield University where he gained his Ph.D. and later at Oxford University, he lectured for a time at the Borough Polytechnic, London, before joining the Park Gate Company in June, 1939, as Assistant Chief Metallurgist. He was appointed Chief Metallurgist in 1943.

Dr. Davies is a Fellow of the Institution of Metallurgists and an Associate of the Institution of Mechanical Engineers. He has previously acted in a consultative capacity to the electricity authorities in the Rotherham area.

▶ Dr. C. H. DESCH, F.R.S., Past-President, has been made an Honorary Member of the Institute.

▶ Mr. A. G. DUCE has taken up an appointment with Messrs. Joseph Lucas, Ltd., Burnley.

▶ Mr. C. E. DWORJACK has been appointed chief mechanical engineer with the Orinoco Mining Company, Venezuela, a subsidiary company of the U.S. Steel Corporation.

▶ Dr. R. GENDERS, Consultant Metallurgist, has changed his address to 40 Grosvenor Gardens, London, S.W.1.

▶ Mr. K. H. GLOAG has retired from his position as a Director of Messrs. J. J. Habershon and Sons, Ltd.

▶ Mr. J. D. GILCHRIST has been appointed lecturer in the Department of Metallurgy, King's College, Newcastle-upon-Tyne.

▶ Mr. E. J. HANCOCK has resigned from his position as Blast-Furnace Manager with the South Durham Steel and Iron Co., Ltd., West Hartlepool.

▶ Mr. N. J. JONES has left the Somerset Wire Co., Ltd., to take up an appointment as Shift Superintendent with the Aluminium Wire and Cable Co., Ltd., Swansea.

▶ Mr. L. F. KORB has left Brazil for New York.

▶ Mr. R. L. LONG is at the Carnegie Institute of Technology, Pittsburgh, taking a post-graduate course in Metallurgy.

▶ Mr. G. W. MILES has left the Park Gate Iron and Steel Co., Rotherham, to take up an appointment in the Research Laboratory of Messrs. Edgar Allen and Co., Ltd., Sheffield.

▶ Mr. D. C. MOORE has left the Department of Industrial Metallurgy at Birmingham University to take up an appointment with the Aluminium Development Association in London.

▶ Colonel J. B. NEILSON, having attained the normal retiring age after 23 years' association with Messrs. Richard Thomas and Baldwins, Ltd., relinquished his office of Director and Joint Managing Director of the Company, on 31st December, 1950.

▶ Mr. J. J. PICK has left the Birmingham Small Arms Co. to take up an appointment as Research Fellow in Industrial Metallurgy at Birmingham University.

▶ Mr. R. W. ROBINSON has left the Metallurgical Laboratory, H.M. Dockyard, Malta, to take up an appointment at the Central Metallurgical Laboratory, Emsworth, Hants.

▶ R. J. RYMAN has left the British Iron and Steel Research Association to take up an appointment as Research Engineer with Messrs. Wm. Jessop and Sons, Ltd.

▶ Mr. L. STANSFIELD has left the English Electric Co., Stafford, to take up an appointment as Senior Metallurgist with the Steel Company of Wales, Port Talbot.

▶ Mr. R. W. THORLEY has left the British Non-Ferrous Metals Research Association to take up an appointment with McKechnie Brothers, Ltd., Birmingham.

▶ Dr. M. TIGERSCHIÖLD, Director of Research, Jernkontoret, Sweden, has been awarded the Carl Lueg Medal of Verein deutscher Eisenhüttenleute.

▶ Mr. E. T. TURKDOGAN has taken up an appointment in the Research and Development Department of the British Oxygen Co., Ltd.

▶ Mr. R. R. WILLIAM has been awarded the B.Eng. degree, in Metallurgy, of the University of Liverpool, and is now with the Ministry of Supply Division of Atomic Energy.

▶ Mr. R. A. M. WRIGHT has left the Clydesdale Works of Messrs. Stewarts and Lloyds, Ltd., and is now at their Corby Works.

Obituary

Sir EDWARD J. GEORGE, a former Director and General Manager of the Consett Iron Company, Ltd., and an Honorary Vice-President of the Institute, on 25th October, 1950.

Mr. F. M. OSBORN, Chairman of Samuel Osborn and Co., Ltd., on 8th November, 1950.

Mr. E. A. WILLIAMS, Chairman and Managing Director of the Clayton Tin Plate Co., Ltd., on 16th November, 1950.

Mr. P. FRIEDMANN of Messrs. Ambores Ltd., London, on 25th November, 1950.

CONTRIBUTORS TO THE JOURNAL

I. E. Thomas.—Member of the research staff at the British Iron and Steel Research Association's Laboratories at Sketty Hall. Mr. Thomas was educated abroad and received his early training in Canada, specializing in the design and manufacture of very fine machine tools for the optical and horological industries. He was appointed Instrument Engineer and Chief Engineer, Technical Section, of Magnesium Metals Corporation, Ltd., just before the war, and subsequently became Research Assistant to Professor R. N. Arnold, engaged on a D.S.I.R.-sponsored project dealing with cutting metals. He joined the Research Staff of B.I.S.R.A. in its early days at Sketty Hall. Mr. Thomas is a Member of the Society of Instrument Technology.

J. O. Lay, A.R.I.C.—Technical Secretary to the Methods of Analysis Committee and its Sub-Committees, of the Metallurgy (General) Division, the British Iron and Steel Research Association.

Mr. Lay was born in 1914 and received a secondary-school education followed by evening-class studies at Woolwich Polytechnic, for a B.Sc. degree.

D. A. Winton

W. Ernest

He has worked in the laboratories of several industrial firms including the Ford Motor Co., Ltd., the Gramophone Company, Ltd., Hayes, and the Plessey Company, Ltd., Ilford, and has also spent three years at the Royal Arsenal.

Mr. Lay has had considerable experience in general chemistry, research, and physical metallurgy. He has held his present position since 1947.

D. A. Winton, B.Sc.(Eng.), A.M.I.C.E., A.M.I.Mech.E.—Technical Secretary of the Mechanical Working Division of the British Iron and Steel Research Association. Mr. Winton obtained the B.Sc.(Eng.) honours degree of London University in 1936. From 1936 to 1939 he was a pupil in the workshops and offices of Messrs. J. and E. Hall, Ltd., of Dartford, Kent, and from 1939 to 1941 he was a member of their technical staff dealing with the performance of refrigerating machinery. He joined the Royal Air Force Volunteer Reserve in 1941 and served as an engineer officer until 1946, initially in charge of the maintenance and repair of a squadron of aircraft, and latterly at a Command Headquarters as a staff officer with the rank of Squadron Leader, on the planning of aircraft maintenance. He took up his present post upon demobilization in 1946.

W. Ernest, G.I.Mech.E.—On the engineering staff of The United Steel Companies, Ltd., Research and Development Department. Mr. Ernest received his technical education at the Newport Technical College and at the College of Technology at Cardiff, and served an engineering apprenticeship with Messrs. John Lysaght, Ltd., Newport, now the Steel Company of Wales (Lysaght Works). He remained with this Company as Technical Assistant to the Works Engineer and later as Plant Engineer until 1948, when he took up his present position in which he is engaged on the design of furnaces and associated equipment.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Third Junior Blast-Furnace Conference

A successful meeting of 74 members was held at Ashorne Hill on 2nd and 3rd October, 1950. Members of the industry gave introductory talks on "The Layout of Blast-Furnace Plant with Particular Reference to the Handling of Raw Materials and Products," and "The Routine Duties of the Junior Blast-Furnace Operator." These were followed by full and lively discussion. Members of B.I.S.R.A. staff then spoke on "Jet Castings," "Cobalt 60," "The Formation of Some Iron Ores," and "The Rotating Disc Gas Cleaner." A small-scale working model of the cleaner was demonstrated. A considerable number of suggestions for future conferences were put forward by members.

AFFILIATED LOCAL SOCIETIES

Manchester Metallurgical Society

A Joint Meeting of the Manchester Metallurgical Society and The Iron and Steel Institute will be held in the Engineers' Club, Albert Square, Manchester, on Wednesday, 14th February, 1951, at 6.30 P.M. Mr. E. J. Heeley, President of the Society, will be in the Chair.

Mr. R. Toye, of the British Iron and Steel Research Association, will give a paper on "Instrumentation of Steelmaking Furnaces—Some of the Problems."

INSTITUTION OF METALLURGISTS

Examination Results

The Examinations of the Institution were held from 28th August to 4th September, 1950, in Birmingham, Glasgow, and London. In addition, Examinations were held in Canada, India, New Zealand, and South Africa. The following candidates were successful:

Licentiateship—D. R. Andrews (Bristol); E. S. Bale (Balham); S. R. A. Langford (Birmingham); R. F. Lee (Birmingham); J. H. Proctor (Churchdown); E. A. Seal (North Wembley); D. White (Atherstone).

Associateship—A. J. Birch (Coventry); L. H. Davenport (Wellington, N.Z.); G. B. Evans (Highcliffe); E. S. Harwood (Birmingham); V. L. James (Enfield); J. H. Kyle (Glasgow); J. McGrandle (Glasgow); D. R. McHarg (Glasgow); H. J. Proffitt (Taplow); D. Sommerville (Motherwell); A. Stuttard (Burnley).

With the exception of D. R. McHarg, all candidates for the Associateship were Licentiates of the Institution.

The following candidates satisfied the Examiners in the Licentiateship Examination or Associateship Examination, but their election is deferred until they have been able to comply with the regulations in respect of age and/or experience:

Licentiateship—H. R. C. Chapman (Peterborough); D. C. Major (London); R. C. Perriton (Worcester Park).

Associateship—J. E. S. Cockle (Beckenham); J. Cumberland (Chesterfield); R. H. T. Dixon (Birmingham); D. Jamieson (Nova Scotia, Canada); A. P. Miodownik (London); J. P. Moore (Liverpool); J. H. Proctor (Churchdown).

With the exception of A. P. Miodownik and J. H. Proctor the candidates are Licentiates of the Institution.

NEWS OF SCIENCE AND INDUSTRY

Kelvin Gold Medal

The Kelvin Medal Award Committee, consisting of the Presidents of The Institutions of Civil Engineers, Mechanical Engineers, Electrical Engineers, Naval Architects, Mining and Metallurgy, Mining Engineers, Engineers and Shipbuilders in Scotland, and The Iron and Steel Institute, have awarded the Kelvin Gold Medal for 1950 to Dr. Theodore von Karman, F.R.S., of Pasadena, California.

Harold Wright Lecture

The Third Triennial Harold Wright Lecture, endowed by Dorman Long and Co., Ltd., was delivered on 28th November, 1950, at the Cleveland Scientific and Technical Institution, Middlesbrough. Sir Andrew McCance, LL.D., D.Sc., F.R.S., gave a lecture on "Production in the Steel Industry—its Growth, Distribution, and Future Course."

British Welding Research Association

Open Days were held at the Engineering and Resistance Welding Laboratories of the British Welding

Research Association at Abington, near Cambridge, on 19th, 20th, and 21st September, 1950.

The exhibits included the new pulsating pressure plant, recently installed in the pressure-vessel laboratory, for testing vessels and other products by repeated application of pressure.

The spot weldability of high-strength light alloys and of low-carbon steels is being investigated in the resistance-welding research department. Recommendations for the spot welding of low-carbon steel sheets have already been published and the present investigation is extended to thicknesses from 24 S.W.G. to ¼ in. The attachment of bolts of several qualities and diameters by resistance-welding is also under investigation.

A number of researches in progress in the fatigue-testing laboratory were demonstrated. The testing method used is that of producing vibrations near the natural frequency of a mass spring system in which the test pieces form the spring. A long-term investigation is concerned with the determination of the effect of residual stresses on the fatigue strength of structural mild steel. These high-tensile stresses are introduced by rapid local induction heating to 500° C.

A heavy crane rail welded to a mild-steel flange plate by heavy intermittent fillet welds, the whole specimen weighing 1 ton, was under test to determine whether fatigue cracks would develop at the stress range to which such points may be subjected in service and whether, if such cracks developed, they would propagate in the rail or in the flange.

The effect of incidental stray flashes, produced inadvertently during welding on high-duty mild-steel components, is being investigated because it has been found that such stray flashes, when situated in zones of high-fatigue stress, may reduce the life of a part. Another investigation has shown that when a welded joint is made in a rolled section, a simple butt weld, provided it is of good quality, is superior to any other type of joint made by using reinforcing straps.

The facilities of the fatigue-testing laboratories are at present severely limited, but a new laboratory which will house the present equipment, a new 100-ton fatigue-testing machine and a crane, is to be built at Abington.

Conference on Heat Transfer

The advance of knowledge in the mechanism of transference of heat, and in the design of apparatus making use of such knowledge, will be the subject matter for discussion at a conference to be held in London on 11th–13th September, 1951. The Institution of Mechanical Engineers, with the co-operation of other kindred societies in Britain, and of societies in the British Commonwealth and Europe, is arranging for the presentation of groups of papers on the many aspects of the subject.

The American Society of Mechanical Engineers with the co-operation of other societies in the western hemisphere, is working jointly with the Institution in arranging similarly for the preparation of papers from American authors for presentation in London.

It is proposed to restrict the papers to developments which have taken place in the last ten years, from 1940 to 1950, and the following main headings have been agreed as covering the field of the discussion: heat transfer with change of state; heat transfer between fluids and surfaces; conduction in solids and fluids; radiation, instrumentation, measurement techniques and analogies; special problems such as heat transfer in turbine blade cooling, in liquid metals, in gas turbines, and in piston engines, the mercury boiler, etc.

The following societies in this country, the British Commonwealth, and Europe are co-operating with the Institution:

The Belfast Association of Engineers, Institution of Chemical Engineers, Society of Chemical Industry, Institution of Civil Engineers, Institution of Civil Engineers of Ireland, Institution of Electrical Engineers, Institution of Engineers and Shipbuilders in Scotland, Faraday Society, Institute of Fuel, Institution of Gas Engineers, Institution of Heating and Ventilating Engineers, Iron and Steel Institute, Junior Institution of Engineers, Institution of Locomotive Engineers, Manchester Association of Engineers, Institute of Marine Engineers, Institute of Metals, Institution of Mining Engineers, Institution of Naval Architects, North East Coast Institution of Engineers and Shipbuilders, Institute of Petroleum, Physical Society, Institute of Physics, Institution of Production Engineers, Institute of Refrigeration, Royal Aeronautical Society, Society of Engineers, South Wales Institute of Engineers, Textile Institute, Institute of Transport.

The Institution of Engineers, Australia, Institution of Engineers, India, New Zealand Institution of Engineers, Associated Scientific and Technical Societies of South Africa.

The Société Royale Belge des Ingénieurs et des Industriels, Institution of Danish Civil Engineers (Dansk Ingeniørforening), Société des Ingénieurs Civils de France, Koninklijk Instituut van Ingenieurs (Holland), Den Norske Ingeniørforening, Svenska Teknologföreningen, Schweizerischer Ingenieur- und Architekten-Verein.

The American Society of Mechanical Engineers has the co-operation of the following: The American Mathematical Society, American Institute of Chemical Engineers, American Chemical Society, American Society of Refrigerating Engineers, American Society of Heating and Ventilating Engineers, American Institute of Physics, American Institute of Mining and Metallurgical Engineers, American Physical Society, Society of Automotive Engineers, Institute of the Aeronautical Sciences, Engineering Institute of Canada.

International Union of Crystallography

At the invitation of the Swedish National Committee for Crystallography, the Second General Assembly and International Congress of the Union will be held in Stockholm from 27th June to 3rd July, 1951. A local Committee has been established under the Chairmanship of A. Westgren, Vice-President of the Union, with F. E. Wickman as Secretary.

Papers presented at the Congress will cover a wide field and will include new developments in structure determination, metal structures, random and deformed structures, and thermal transformations.

In connnection with the Congress it is proposed to hold a symposium on "Advanced Technique in Structure Determination" and one on "Electron Diffraction in Liquids and Gases."

All correspondence concerning contributions to the Congress should be sent to F. E. Wickman, Stockholm 50, Sweden. All other correspondence should be addressed to the General Secretary of the Union, R. C. Evans, Crystallographic Laboratory, Cavendish Laboratory, Cambridge. Intending participants are asked to inform the Assistant Secretary of the Royal Society.

Institution of Mining and Metallurgy

Sir Lewis L. Fermor, O.B.E., A.R.S.M., D.Sc., F.R.S., formerly with the Geological Survey of India, has been elected President of the Institution of Mining and Metallurgy for the Session 1951–52 and will take office at the Annual General Meeting, to be held on 17th May, 1951.

Verein deutscher Eisenhüttenleute

Dr. O. Petersen, formerly Director of Verein deutscher Eisenhüttenleute, has been made an Honorary Member of that Institute.

National Metallurgical Laboratory of India

The National Metallurgical Laboratory of India, Jamshedpur (Council of Scientific and Industrial Research) was opened on Sunday, 26th November, 1950, by the Honourable Pandit Nehru, Prime Minister of India. Mr. J. R. D. Tata presided.

Metallurgia

With the publication of the November issue the Journal *Metallurgia* celebrated its 'coming of age.' This special Anniversary Issue was devoted to reviews, by leading technical personalities, of the progress in the metal industries during the past 21 years.

It is with regret that we have to announce the retirement of Mr. Charles A. Otto, who has been Editor of *Metallurgia* since its inception in 1929. His work of establishing a technical periodical of outstanding quality is to be continued, from the beginning of 1951, by his colleague Mr. Edgar Holland.

Influence of Residual Stresses in the Fatigue Strength of Structures

A report by Professor M. Ros of Zurich which was published in *Welding Research*, vol. 4, No. 5, was submitted to the Commission on Residual Stresses and Stress Relieving of the International Institute of Welding at the meeting in Paris in June, 1950. A series of fatigue tests was undertaken by Professor Ros to obtain an indication of the effect of residual stresses on fatigue strength. Residual stresses were introduced by forcing a plug into a round hole made in a flat plate, by pinning together two pieces of plate whilst under stress and by welding plugs into holes trepanned in flat plates. It is concluded that the effect of residual stresses on fatigue strength is not likely to exceed 8%.

Samuel Osborn and Co., Ltd.

Mr. Samuel E. Osborn has been appointed Chairman of Samuel Osborn and Co., Ltd., in succession to the late Mr. F. M. Osborn. Mr. Frank A. Hurst becomes Deputy Chairman whilst retaining his present position of Managing Director. Mr. Brian C. Pye-Smith has been appointed a Director of the Company.

British Standards Institution

The death has been announced of Percy Good, C.B.E., M.I.E.E., Director of the British Standards Institution, on 2nd December, 1950.

Grey Iron-Founding

In the latest productivity team report published by the Anglo-American Council on Productivity, the members of the team, representing British grey iron-founding, find that although the best production index in this country may equal the best in America, the average in the U.S. is much better. In fact, the U.S. industry is about twice as productive as our own.

'Metamic'

The Morgan Crucible Co., Ltd., have for some time been actively engaged in the development of metal–ceramic materials, and have registered the trade mark 'Metamic' to cover their products of this type.

Messrs. Honeywell-Brown, Ltd.

A Sales and Service Office associated with the Blantyre Works of Honeywell-Brown, Ltd., has been opened to provide assistance on the technical application and maintenance of the Brown ElectroniK Potentiometer Pyrometers and Protectoglos. Information on the application and servicing of these instruments may be obtained from Honeywell-Brown, Ltd., Block 4, Scottish Industrial Estates, Blantyre, Lanarkshire.

Birlec Lectromelt Furnace

The Birlec Lectromelt Furnace of ½-ton capacity and rated at 300 kVA., which was fitted with a contactor-type controller when it was first installed in 1946, has now been fitted with the latest type of rotary controller.

It is claimed that with the new controller greater electrode speeds may be obtained without hunting and that short circuits may be cleared more quickly. When melting high-speed steel a 10% saving in kWh./ton has been obtained and at the same time electrode consumption and refractory wear have been reduced. Further improvement in efficiency has also been obtained with the introduction of a new electrode gland.

New Blast-Furnace

The new No. 2 furnace of the Steel Company of Wales at Margam was blown in on the 7th November, 1950. This furnace, having a hearth diameter of 25 ft. 9 in., is the largest in Great Britain and is rated to produce 1000 tons of basic iron per day. It is one of the group which will supply hot metal to the steelplant at the Abbey works. The new furnace, like the other at Margam, was designed and built by Ashmore, Benson, Pease and Company, Ltd., of Stockton-on-Tees.

Tungsten Carbide

The manufacturing processes involved in the quantity production of tungsten carbide are shown in the colour film *Hard Metal*, presented by Murex, Ltd. The manufacture is traced from the naturally occurring ores, through the magnetic separation plant and the many chemical processes, to the production of pure tungstic acid.

Each important phase in the reduction of the tungstic acid to the pure metal powder, to be used in the manufacture of 'Hard Metal,' is shown. Fabrication grinding, etc., and the final inspection and packing of the products are depicted. Included in the film are a few examples of the industrial applications of the material.

Bubble Model of a Metal

The 16-mm. silent film "Bubble Model of a Metal," directed by Professor W. H. Bragg, is now in the Central Film Library. The film illustrates the behaviour of a model made to simulate a metal structure. The atoms are represented by small bubbles floating on the surface of a soap solution. The film shows the behaviour of the model under various kinds of distortion (compression, shear, etc.) and demonstrates the processes that are thought to occur in strained metals. It is self-explanatory, but can be used to illustrate a lecture on the mechanical properties of metals.

Industrial Publications

▶ The United Steel Companies, Ltd., have published a brochure entitled "Some Notes on Alloy Steels Containing Lead." The publication deals with the production of alloy steels made at the works of their subsidiary company Samuel Fox and Co., Ltd., to any specific standard but with the addition of lead. The brochure includes a short bibliography of recently published work on lead-treated alloy steels.

▶ Wiggin Nickel Alloys, No. 326, published by Henry Wiggin and Co. Ltd., describes some of the uses of Monel and other nickel alloys in steam power plant. Monel water baths, electrical resistances for cinema dimming equipment, a new gas-fired space heater, and new ceramic-to-metal seals for electrical and radio apparatus are included.

▶ Henry Wiggin and Co., Ltd., Birmingham, have just published a comprehensive handbook dealing with the hot-working, annealing, and pickling of nickel, Monel, and Inconel.

The first section on hot-working deals with suitable fields, hot-working temperatures, and methods of forging and with dies and lubrication.

The second section covers methods suitable for annealing these high-nickel materials, whilst the final section gives full details and formulæ for pickling.

▶ An illustrated digest of high-vacuum equipment for industry, research, and education has been prepared by Messrs. W. Edwards and Co., Sydenham. Brief reference is made to each type of apparatus manufactured by the Company, and performance figures are given.

▶ The range of industrial instruments and controllers manufactured by George Kent, Ltd., Luton, is illustrated and described, in French, in catalogue No. 1002. The catalogue is also available in Italian and will be published in Danish, Swedish, and German.

▶ A catalogue which covers the standard range of automatic starting and control gear has been issued by Contactor Switchgear, Ltd., Wolverhampton. Illustrations and current prices are given.

▶ A recent pamphlet (ref. FD8), issued by the Morgan Crucible Co., Ltd., describes a method for melting cast iron in small quantities in Morgan crucible furnaces. Iron can be melted with complete thermal and metallurgical control without sulphur or phosphorus pick-up and without loss of alloy ingredients.

▶ A brochure of Instruments and Accessories for Radio-Isotope Application, published by the Scientific Instrument Manufacturers' Association in collaboration with the A.E.R.E., Harwell, summarizes the equipment available from British sources for isotope techniques in medicine, research, and industry.

▶ High-speed forging presses are illustrated and described in a 40-page publication issued by the Davy and United Engineering Co., Ltd. Particulars of design, cylinder arrangement, working fluid, drive, and manipulating gear are given. Some special applications of specific presses are included.

Changes of Address

THE BRITISH HYDROMECHANICS RESEARCH ASSOCIATION have closed their London office, and all communications should be sent to: Netteswell Road, Harlow, Essex.

BRITISH COAL UTILISATION RESEARCH ASSOCIATION have closed their office at 13 Grovenor Gardens, and all correspondence should be sent to Randalls Road, Leatherhead, Surrey.

BRITISH TIMKEN LTD., have opened new offices at 93 Hope Street, Glasgow, C.2. (Tel: Glasgow Central 7331–2.)

THE ACTARC WORKS of the Arc Manufacturing Co., Ltd., have removed from Goldhawk Road, London, W.12, to Nitshill, Glasgow.

DIARY

5th Jan.—MANCHESTER ASSOCIATION OF ENGINEERS—"*Automatic Welding*," by E. Hindson—The Engineers' Club, 17 Albert Square, Manchester, 6.45 P.M.

10th Jan.—NORTH WALES METALLURGICAL SOCIETY—"*Cast Irons, their Microstructure and Mechanism of Solidification*," by W. J. Williams—County Primary School, Plymouth Street, Shotton, Chester, 7.15 P.M.

11th Jan.—LIVERPOOL METALLURGICAL SOCIETY—"*The New Nodular Cast Irons*," by H. Morrogh—Electricity Service Centre, Whitechapel, Liverpool, 7.0 P.M.

13th Jan.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—"*Steelworks Refractories*," by R. Higgins—Central Library, Swansea, 6.30 P.M.

19th Jan.—WEST OF SCOTLAND IRON AND STEEL INSTITUTE—"*Development of Bolt Manufacture*," by A. P. Newall—39 Elmbank Crescent, Glasgow, 6.45 P.M.

22nd Jan.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS (Joint Meeting with the Engineers' Group of The Iron and Steel Institute)—"*The Abbey Works of the Steel Company of Wales, Ltd.*," by W. F. Cartwright—Royal Victoria Station Hotel, Sheffield, 6.15 P.M.

23rd Jan.—INSTITUTION OF ENGINEERING INSPECTION (Wolverhampton Branch)—"*The Metallurgist and Engineering Inspection*," by R. J. Brown—Compton Grange, Wolverhampton, 7.15 P.M.

23rd Jan.—THE INSTITUTE OF WELDING (Sheffield and District Branch)—"*The Welding of Hardenable Alloy Steels*," by K. Winterton—College of Commerce and Technology, Pond Street, Sheffield, 7.0 P.M.

25th Jan.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS (Joint Meeting with the Sheffield Section of the Institute of Metals)—"*Cast Corrosion-Resisting Alloys*," by M. M. Hallett—Grand Hotel, Sheffield, 6.15 P.M.

31st Jan.—INSTITUTE OF BRITISH FOUNDRYMEN—Documentary films, "*Flawless and British*" and "*And Now*," by Messrs. F. H. Lloyd and Co., Ltd.—Waldorf Hotel, Aldwych, W.C.2, 7.30 P.M.

31st Jan.—INSTITUTE OF WELDING—"*Continuous Welded Structures*," by W. S. Atkins—Institution of Civil Engineers, Great George Street, London, S.W.1.

TRANSLATION SERVICE

(The previous announcement was made in the December, 1950, issue of the *Journal*, p. 360.)

TRANSLATIONS AVAILABLE

No. 413 (Czech). P. SKULARI: "Determination of Internal Stresses of the Second Type." (*Druký Pracovní Sjezd Horních a Hutních Inženýrů* 1947, May, pp. 127–144).

No. 414 (German). W. JELLINGHAUS: "New Developments in the Non-Destructive Testing of Materials by Electrical and Magnetic Means." (*Stahl und Eisen*, 1950, vol. 70, June 22, pp. 552–560; discussion, pp. 560–561).

No. 415 (German). T. KOOTZ and W. OELSEN: "A Contribution to the Metallurgy of the Blast-Furnace." (*Archiv für das Eisenhüttenwesen*, 1950, vol. 21, Mar./Apr., pp. 77–88). (Translated by Dr. P. Herasymenko and made available through the courtesy of the The United Steel Companies, Ltd., Research and Development Department, Stocksbridge, near Sheffield.

TRANSLATION IN COURSE OF PREPARATION

(German). W. KRÄMER: "The Use of Roller Bearings in the Housings of Thin Sheet Hot Mills." (*Stahl und Eisen*, 1950, vol. 70, Oct. 12, pp. 925–929).

CHARGES FOR COPIES OF TRANSLATIONS—The charge for the above translations is £1 for the first copy and 10*s.* for each additional copy of the same translation. Requests should be accompanied by a remittance. These translations are not available on loan from the Joint Library.

TRANSLATIONS PREPARED AT MEMBERS' REQUEST—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether they can be prepared for inclusion in the Series.

ABSTRACTS OF CURRENT LITERATURE *and* BOOK NOTICES

IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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LIST OF PERIODICALS EXAMINED BY THE ABSTRACTING SERVICE

Academia Brasileira de Ciencias (Rio de Janeiro)
Anais

Académie Bulgare des Sciences (Sofia)
Comptes Rendus

Académie Polonaise des Sciences Techniques (Warsaw)
Annales

Académie des Sciences (Paris)
Comptes Rendus

Accademia Nazionale dei Lincei (Rome)
Rendiconte (Fisiche Matematische e Naturali)

Acero y Energia (Barcelona)

Acid Open-Hearth Research Association (Pittsburgh)
Bulletin

Acier (Paris)

Acta Crystallographica (London)

Acta Mineralogica Petrographica (Szeged, Hungary)

Acta Polytechnica (Stockholm)

Advancement of Science (London)

Aeroplane (London)

Aircraft Engineering (London)

Aircraft Production (London)

Alloy Castings Bulletin (New York)

Alloy Metals Review (Widnes, Lancs.)

Alluminio (Milan)

Aluminium (Budapest)

Aluminium Courier (London)

Aluminium Development Association (London)
Information Bulletin

Aluminium Laboratories, Ltd. (Montreal)
Abstract Bulletin

American Ceramic Society (Columbus, Ohio)
Bulletin
Journal

American Chemical Society (Washington, D.C.)
Journal

American Electroplaters' Society (Jenkintown, Pa.)
Proceedings
Research Reports

American Foundryman (Chicago)

American Foundrymen's Society (Chicago)
Transactions

American Gas Association (New York)
Monthly
Natural Gas Department, Proceedings
Proceedings

American Institute of Electrical Engineers (New York)
Transactions

American Institute of Mining and Metallurgical Engineers (New York)
Blast-Furnace and Raw Materials Committee, Proceedings
Electric Furnace Steel Conference, Proceedings
National Open-Hearth Committee, Proceedings
Symposia Series
Technical Publications
Transactions

American Iron and Steel Institute (New York)
Annual Statistical Reports
Contributions to the Metallurgy of Steel
Regional Technical Meetings
Yearbook

American Journal of Physics (New York)

American Journal of Science (New Haven, Conn.)

American Petroleum Institute (New York)
Proceedings, Production Section

American Society of Mechanical Engineers (New York)
Transactions

American Society for Metals (Cleveland, Ohio)
Review of Metal Literature
Transactions

American Society for Naval Engineers (Washington, D.C.)
Journal

American Society for Testing Materials (Philadelphia)
Bulletins
Proceedings
Standards
Symposia

American Water Works Association (New York)
Journal

American Welding Society (New York)
Miscellaneous Publications

American Zinc Institute (New York)
Journal

Anales de Fisica y Química (Madrid)

Anales de Ingeniería (Bogota, Colombia)

Anales de Mecanica y Electricidad (Madrid)

Analyst (London)

Analytica Chimica Acta (New York and Amsterdam)

Analytical Chemistry (Washington, D.C.)

Annales des Mines (Paris)
Mémoires

Applied Mechanics Reviews (New York)

Applied Research Laboratories (Glendale, Cal.)
Reports
Spectrographic News Letter

Applied Scientific Research (The Hague)

Archiv für das Eisenhüttenwesen (Düsseldorf)

Archiv für Metallkunde (Heidelberg and Berlin)

Archives des Sciences Physiques et Naturelles (Geneva)

LIST OF PERIODICALS

Arkiv för Kemi Stockholm and Upsala)
Arkiv för Mineralogi och Geologi (Stockholm and Upsala)
Asociación Química Argentina (Buenos Aires)
Anales
Associação Brasileira de Metais (São Paulo)
Boletim
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Association des Industriels de Belgique (Brussels)
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Association des Ingénieurs de la Faculté Polytechnique de Mons (Mons)
Publications
Association of Iron and Steel Engineers (Pittsburgh)
Yearly Proceedings
Association Technique de l'Acier et des Métaux Non-Ferreux (Paris)
Bulletin d'Information et de Documentation
Atomics (London)
Australasian Engineer (Sydney)
Australasian Institute of Mining and Metallurgy (Melbourne)
Proceedings
Australia—Defence Research Laboratories (Maribyrnong)
Circulars
Plating Notes
Australian Foundry Trade Journal (Sydney)
Australian Journal of Applied Science (Melbourne)
Australian Journal of Scientific Research (Series A) (Melbourne)
Automobile Engineer (London)
Avtogennoe Delo (Moscow)

BEAMA Journal (London)
B.H.P. Review (Melbourne)
Ball Bearing Journal (Luton)
Báňsky Obzor (Prague)
Bányászati és Kohászati Lapok (Budapest)
Battelle Memorial Institute (Columbus, Ohio)
Miscellaneous Publications
Bell Laboratories Record (New York)
Bell System Technical Journal (New York)
Bell Telephone Magazine (New York)
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Technical Publications
Berg- und Hüttenmännische Monatshefte (Vienna)
Betrieb und Fertigung (Vienna)
Birmingham Metallurgical Society (Birmingham)
Journal
Blad för Bergshandteringens Vänner (Stockholm)
Blast-Furnace and Steel Plant (Pittsburgh)
Board of Trade (London)
German Division (Document Unit)
Board of Trade Journal (London)
Boletin Minero e Industriel (Bilbao)
Bradley's Magazine (Darlaston, Staffs.)
British Abstracts (London)
British Cast Iron Research Association (Birmingham)
Bulletin
British Ceramic Abstracts (Stoke-on-Trent)
British Ceramic Society (Stoke-on-Trent)
Transactions
British Coal Utilisation Research Association (London)
Monthly Bulletin
Quarterly Gazette
British Coke Research Association (London)
Technical Papers
Reports of Conferences
British Columbia Research Council (Vancouver)
Annual Reports
Technical Bulletin
British Dental Journal (London)
British Engineering (London)
British Industrial Finishing (Leighton Buzzard)
British Institution of Radio Engineers (London)
Journal
British Intelligence Objectives Sub-Committee (London)
Reports
British Iron and Steel Federation (London)
Monthly Statistical Bulletin
Statistical Yearbook
Steel News
British Iron and Steel Research Association (London)
Technical Reports
British Journal of Applied Physics (London)
British Non-Ferrous Metals Research Association (London)
Bulletin
British Scientific Instrument Research Association (London)
Bulletin
British Shipbuilding Research Association (London)
Journal
British Standards Institution (London)
British Standards
British Steel Founders' Association (Sheffield)
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British Steelmaker (London)
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Reports
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Bureau of Mines (Washington, D.C.).
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Reports of Investigations
Technical Papers
Business (London)

Cambridge Philosophical Society (London)
Proceedings
Canadian Institute of Mining and Metallurgy (Montreal)
Canadian Mining and Metallurgical Bulletin
Transactions
Canadian Journal of Research (Ottawa)
Canadian Metals (Toronto)
Canadian Mining Journal (Quebec)
Centraal Instituut voor Materialenonderzoek (Delft)
Circulaire
Centre de Documentation Sidérurgique (Paris)
Bulletin Analytique
Circulaires d'Informations Techniques
Circulaires d'Informations Techniques (Suppl.)
Traductions
Centre National de la Recherche Scientifique (Paris)
Bulletin Analytique
Ceramic Digest (St. Albans)
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Cercle d'Etudes des Métaux (St. Etienne)
Bulletin
Chaleur et Industrie (Paris)
Chambre Syndicale de la Sidérurgie (Paris)
Bulletin
Chemical Abstracts (Columbus, Ohio)
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Chemical Engineering (New York)
Chemical Engineering Group (London)
Proceedings
Chemical Engineering Mining Review (Melbourne)
Chemical and Engineering News (Washington, D.C.)
Chemical Engineering Progress (New York)
Chemical, Metallurgical and Mining Society of South Africa (Johannesburg)
Journal
Chemical Society (London)
Journal
Chemické Listy (Prague)
Chemie-Ingenieur-Technik (Weinheim, Germany)
Chemisch Weekblad (Amsterdam)
Chemist Analyst (Phillipsburg, N.J.)
Chemistry and Industry (London)
Chimica e Industria (Milan)
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Chimie et Industrie (Paris)
Claycraft (London)
Coke and Gas (London)
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Bulletin
Yearbook
Collection des Travaux Chimiques de Tchécoslovaquie (Prague)
Colliery Guardian (London)
Colorado Scientific Society (Denver, Colo.)
Proceedings
Combined Intelligence Objectives Sub-Committee (London)
Reports
Comisiunii de Standardizare (Bucharest)
Boletinul de Standardizare
Commonwealth Engineer (Melbourne)
Compressed Air and Hydraulic Engineering (London)
Copper Development Association (London)
Miscellaneous Publications
Corrosion (Houston, Texas)
Costruzioni Metalliche (Milan)
Council of Ironfoundry Associations (London)
Industrial Welfare Bulletins
Council for Scientific and Industrial Research (Melbourne)
Aeronautical Research Reports
Bulletin
Division of Aeronautics, Reports
Division of Tribophysics, Physical Metallurgy Reports
Journal

Coventry Engineering Society (Coventry)
Journal

Danish Academy of Technical Sciences (Copenhagen)
Dansk Teknisk Tidsskrift (Copenhagen)
Department of Mines and Resources (Ottawa)
Bulletins (Mines and Geology Branch)
Reports
Department of Scientific and Industrial Research (London)
Reports
Die Castings (Cleveland)
Diesel Engine Users' Association (London)
Proceedings
Discovery (Norwich)
Documentation Métallurgique (St. Etienne)
Dominion Bureau of Statistics (Ottawa)
Reports
Du Pont Magazine (Wilmington, Del.)
Durham University Philosophical Society (Durham)
Proceedings
Dyna (Barcelona)

E.S.C. News (Sheffield)
Ebbw Vale Metallurgical Society (Ebbw Vale)
Proceedings
Écho des Mines (Paris)
Edgar Allen News (Sheffield)
Edison Electric Institute (Philadelphia)
Bulletin
Eidgenossische Materialprüfungs- und Versuchsanstalt für Industrie Bauwesen und Gewerbe (Zürich)
Berichte
Electrical Engineer and Merchandiser (Melbourne)
Electrical Power Engineer (London)
Electrical Review (London)
Electrical Times (London)
Electrician (London)
Electrochemical Society (Baltimore, Md.)
Journal
Transactions
Electrodepositors' Technical Society (London)
Journal
Electromet Review (New York)
Electronic Engineering (London)
Electroplating (London)
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Endeavour (London)
Engineer (London)
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Faraday Society (London)
General Discussions
Transactions
Fédération des Associations Belges d'Ingénieurs (Brussels)
Revue d'Informations
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Final Reports
Technical Bulletins
Fisher Scientific Company (Pittsburgh)
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Fonderie (Paris)
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Journal
Freyn Design (Chicago)
Fuel (London)
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G.E.C. Journal (London)
Galvano (Paris)
Gas Heat in Industry (Leighton Buzzard, England)
Gas Times (Leighton Buzzard, England)
Gas World (London)
Gazzetta Chimica Italiana (Rome)
Génie Civil (Paris)
Geological, Mining and Metallurgical Society of India (Calcutta)
Bulletin
Quarterly Journal
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Geological Survey (London)
Bulletin
Memoirs
Geological Survey, India (Calcutta)
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Geological Survey, U.S.A. (Washington, D.C.)
Bulletins
Circulars
Professional Papers
Geologiska Föreningens (Stockholm)
Förhandlingar
Gjuteriet (Stockholm)
Glównego Instytutu Metalurgii i Odlewnictwa (Gliwice)
Prace Badawcze
Glückauf (Essen)
Groupement pour l'Avancement des Méthodes Spectographiques (Paris)
Congrès

Hot Dip Galvanizers Association (Oxford)
Miscellaneous Publications
Hutnické Listy (Prague)
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Illinois University, Engineering Experiment Station (Urbana, Ill.)
Bulletins
Circulars
Imperial Institute (London)
Bulletin
Reports of Mineral Resources
Imperial Smelting Corporation (Avonmouth)
Monthly Abstracts
Index Aeronauticus (London)
Indian Academy of Sciences (Bangalore)
Proceedings, Sections A and B
Indian Chemical Society (Calcutta)
Journal
Indian and Eastern Engineer (Calcutta)
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Indian Institute of Metals (New Delhi)
Transactions
Indian Institute of Science (Bangalore)
Reprints
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Proceedings
Industria y Química (Buenos Aires)
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I.V.A.
Institut pour l'Encouragement de la Recherche Scientifique dans l'Industrie et l'Agriculture (Brussels)
Comptes Rendus de Recherches
Institut National de Recherches Technologiques de Roumanie (Bucharest)
Bulletin
Institut de Recherches de la Sidérurgie (Paris)
Publications
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Institution of Engineers and Shipbuilders in Scotland (Glasgow)
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Institution of Locomotive Engineers (London)
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Institution of Mechanical Engineers (London)
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Institution of Metallurgists (London)
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Institution of Mining Engineers (London)
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Institution of Mining and Metallurgy (London)
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Institution of Naval Architects (London)
Transactions
Institution of Production Engineers (London)
Journal
Instituto Geologico y Minero de España (Madrid)
Boletin
Mapa Geologica
Memorias
Notas y Comunicaciones
Instituto del Heirro y del Acero (Madrid)
Instituto de la Soldadura (Madrid)
Boletin de Información
Publicaciones
Instrument Practice (London)
International Institute of Welding (Paris)
Bibliographical Bulletin of Welding
Iron Age (New York)
Iron and Coal Trades Review (London)
Iron and Steel (London)
Iron and Steel Engineer (Pittsburgh)
Istanbul University (Istanbul)
Revue de la Faculté des Sciences

Jassy—Institut Polytechnique de Jassy (Jassy, Rumania)
Jernindustri (Oslo)
Jernkontorets Annaler (Stockholm)
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Reports
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Mitteilungen der Berg- und Hüttenmännischen Abteilung
Kyushu University, Faculty of Engineering (Kyushu, Japan)
Memoirs

Lastechniek (The Hague)
Leichtmetall (Singen-Hohentwiel)
Light Metal Age (Chicago)
Light Metals (London)
Lincolnshire Iron and Steel Institute (Scunthorpe)
Proceedings
Liverpool Engineering Society (Liverpool)
Transactions

Machine Design (Cleveland, Ohio)
Machine Shop Magazine (London)
Machinery (Brighton, Sussex)
Machinist (London)
Manchester Association of Engineers (Manchester)
Transactions
Maquinas e Metais (Lisbon)
Maschinenmarkt und Elektrowirtschaft (Vienna)
Massachusetts Institute of Technology (Cambridge, Mass.)
Proceedings of Summer Conference on Spectroscopy
Materials and Methods (New York)
Max-Planck-Institut für Eisenforschung (Düsseldorf)
Mitteilung
Mécanique Documentation (Paris)
Mechanical Engineering (New York)
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Melbourne University (Melbourne)
Reprints of Communications
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Mémoires
Metal Finishing (New York)
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Metal Industry (London)
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Proceedings
Metal Powder News (New York)
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Metal Progress (Cleveland, Ohio)
Metal Treatment and Drop Forging (London)
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Métallurgie (Paris)
Metall (Berlin)
Metals Review (Cleveland)
Metalurgia y Electricidad (Madrid)
Métaux et Corrosion (St. Germain-en-Laye, France)
Metaux et Industries (Paris)
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Engineering Research Bulletin
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Microtecnic (Lausanne)
Midwest Engineer (Chicago)
Mine and Quarry Engineering (London)
Mineracão e Metallurgia (Rio de Janeiro)
Mineralogical Magazine (London)
Minerals Yearbook (Washington, D.C.)
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Mining, Geological and Metallurgical Institute of India
Transactions
Mining Institute of Scotland (Glasgow)
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Mining Journal (London)
Mining Magazine (London)
Ministry of Fuel and Power (London)
Papers and Annual Reports of the Safety in Mines Research Board
Ministry of Health (London)
Annual Reports on Alkali Works
Ministry of Supply (London)
Miscellaneous Publications
Minnesota University, Engineering Experiment Station (Minneapolis Minn.)
Bulletin
Technical Papers
Missouri University School of Mines and Metallurgy (Rolla, Mo.)
Bulletin
Modern Metals Chicago)
Motor Ship (London)
Müegyetemi Kozlemenyek (Budapest)
Murex Review (Rainham, Essex)
Mysore Geological Department (Bangalore)
Records

Naples University—Istituto di Tecnologie (Naples)
Publications
Nassau (Staten Island, N.Y.)
National Bureau of Standards (Washington, D.C.)
Building Materials and Structures
Circulars
Commercial Standards
Handbooks
Journal of Research
Technical News Bulletin
National Research Council (Washington, D.C.)
Bulletin Series
National Smoke Abatement Society (London)
Smokeless Air
Nature (London)
Neue Giesserei (Düsseldorf)
New Zealand Engineering (Wellington)
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Newcomen Society (London)
Transactions
Nickel Bulletin (London)
Non-Destructive Testing (Chicago)
Norsk Geologisk Tidsskrift (Oslo)
North-East Coast Institution of Engineers and Shipbuilders (Newcastle-on-Tyne)
Transactions
Nova Scotian Institute of Science (Halifax, Nova Scotia)
Proceedings
Nucleonics (New York)

Ohio State University, Engineering Experiment Station (Columbus, Ohio)
Bulletin
Circulars

Oil Engine and Gas Turbine (London)
Ontario Research Foundation (Toronto)
Reports
Operational Research Quarterly (London)
Optical Society of America (New York)
Journal
Ossature Métallique (Brussels)
Österreichische Akademie der Wissenschaften (Vienna)
Anzeiger
Overseas Engineer (London)

Peintures, Pigments, Vernis (Paris)
Petroleum Technology (London)
Philippine Geologist (Manila)
Philips' (N.V.) Gloeilampenfabrieken, Laboratoria (Eindhoven, Holland)
Separaats
Philips Research Reports (Eindhoven, Holland)
Philips Technical Review (English Edition of Philips Technische Rundschau) (Amsterdam)
Philosophical Magazine (London)
Physica (The Hague)
Physical Review (New York and Lancaster, Pa.)
Physical Society (London)
Proceedings
Reports of the Progress of Physics
Physical Society of Japan (Tokyo)
Journal
Plating (Jenkintown, Pa.)
Post Office Electrical Engineers' Journal (Epsom, Surrey)
Powder Metallurgy Bulletin (Yonkers, N.Y.)
Power and Works Engineering (London)
Pratique du Soudage (Brussels)
Product Engineering (New York)
Production Engineering Research Association (Melton Mowbray)
Bulletin
Product Finishing (London)
Products Finishing (Cincinnatti)
Pro-Metal (Berne, Switzerland)
Przeglad Techniczny (Warsaw and Lodz)
Purdue University, Engineering Experimental Department (Lafayette, Ind.)
Engineering Extension Series
Engineering Research Series

Quarterly Journal of Mechanics and Applied Mathematics (Oxford)
Queensland Department of Mines (Brisbane)
Annual Reports
Queensland Mining Journal (Brisbane)

Railway Engineering Abstracts (London)
Recherche Aéronautique (Paris)
Recueil des Travaux Chimiques des Pays-Bas (The Hague)
Refractories Journal (London)
Research (London)
Research Association of British Paint, Colour and Varnish Manufacturers' Association (Teddington)
Review
Review of Scientific Instruments (New York)
Reviews of Modern Physics (New York and Lancaster, Pa.)
Revista de Ciencia Aplicada (Madrid)
Revista de Química Industrial (Rio de Janeiro)
Revistele Technice Agir (Bucharest)
Revue de l'Aluminium (Paris)
Revue Générale de Mécanique (Paris)
Revue de l'Industrie Minérale (St. Etienne, France)
Revue de Métallurgie (Paris)
Revue des Produits Chimiques (Paris)
Revue de la Soudure (Lastijdschrift) (Brussels)
Revue Technique Luxembourgeoise (Luxembourg)
Revue Universelle des Mines (Liège)
Rheology Bulletin (New York)
Ricerca Scientifica (Rome)
Roll'schen Eisenwerke A.G. (Gerlafingen, Switzerland)
Mitteilungen
Werkzeitung
Roval Metal Finishing (Enfield, Mddx.)
Royal Aeronautical Society (London)
Journal
Royal Artillery (London)
Journal
Royal Australian Chemical Institute (Melbourne)
Journal and Proceedings
Royal Canadian Institute (Toronto)
Proceedings
Transactions
Royal Institute of British Architects (London)
Journal
Royal Institute of Chemistry (London)
Journal and Proceedings
Lectures
Royal Institution (London)
Proceedings
Royal Microscopical Society (London)
Journal
Royal Mint (London)
Annual Reports
Royal Society (London)
Philosophical Transactions
Proceedings Section A
Royal Society of Arts (London)
Journal
Royal Society of Canada (Ottawa)
Transactions
Royal Society of Edinburgh (Edinburgh)
Proceedings. Section A.
Royal Society of New South Wales (Sydney)
Journal and Proceedings
Royal Statistical Society (London)
Journal
Rozpravy (Prague)

Schweissen und Schneiden (Brunswick)
Schweisstechnik (Vienna)
Schweizer Archiv für angewandte Wissenschaft und Technik (Annales Suisses des Sciences Appliquées et de la Technique) (Solothurn, Switzerland)
Science (Washington, D.C.)
Science Abstracts (London)
Science and Art of Mining (Wigan)
Science and Engineering (Calcutta)
Science Progress (London)
Scientific Lubrication (Wellington, Salop)
Scientific Research Institute (Tokyo)
Journal
Reports
Scope (London)
Servizio di Documentiazone Tecnica (Rome)
Bollettino di Documentazione Tecnica
Sheet Metal Industries (London)
Sheet and Strip Metal Users' Association (London)
Annual Proceedings
Shipbuilder (Newcastle-on-Tyne)
Shipping World (London)
Silicates Industriels (Brussels)
Smithsonian Institution (Washington, D.C.)
Annual Report
Sociedad Nacional de Mineria (Santiago)
Boletin Minero
Sociedade Geologica de Portugal (Oporto)
Boletin
Société d'Encouragement pour l'Industrie Nationale (Paris)
Industrie National
Société des Ingeniéurs Civils de France (Paris)
Bulletin
Mémoires
Société Royale Belge des Ingénieurs et des Industriels (Brussels)
Bulletin Technique
Mémoires
Société Scientifique de Bruxelles (Brussels)
Annales. Série 1. Sciences Mathématiques et Physiques
Sociétés Chimiques Belges (Brussels)
Bulletin
Society of Antiquaries, Newcastle-on-Tyne
Archaelogia Aeliana
Proceedings
Society of Automotive Engineers (New York)
Handbook
Quarterly Transactions
SAE Journal
Society of Chemical Industry (London)
Annual Reports on the Progress of Applied Chemistry
Journal
Society of Chemical Industry of Victoria (Melbourne)
Proceedings
Society of Engineers (London)
Journal
Society of Experimental Stress Analysis (Cambridge, Mass.)
Proceedings
Society of Glass Technology (Sheffield)
Journal
Society of Instrument Technology (London)
Transactions
South African Bureau of Standards (Pretoria)
Specifications
South African Institute of Electrical Engineers (Johannesburg)
Transactions
South African Institution of Engineers (Johannesburg)
Journal
South Australia, Chief Inspector of Factories and Steam Boilers (Adelaide)
Annual Reports
South Australia, Department of Mines (Adelaide)
Geological Survey Bulletins
Mining Reviews
South Wales Institute of Engineers (Cardiff)
Proceedings
Spectrochimica Acta (Vatican City)

Staffordshire Iron and Steel Institute (Walsall)
Proceedings
Stahl und Eisen (Düsseldorf)
Stanki i Instrument (Moscow)
Statens Provningsanstalt, Stockholm
Berättelse
Meddelande
Steam Engineer (London)
Steel (Cleveland, Ohio)
Steel Facts (New York)
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Steel Products Manual (New York)
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Structural Engineer (London)
Sudostroyennie (Leningrad)
Suffolk Iron Foundry (1920), Ltd. (Stowmarket, Suffolk)
Sif Tips
Sulzer Technical Review (Winterthur, Switzerland)
Svařování (Prague)
Sveriges Geologiska Undersökning (Stockholm)
Årsbok
Svetsaren (Gothenburg)
Svetsen (Stockholm)
Swansea and District Metallurgical Society (Gorseinon)
Papers

Technik (Berlin)
Technique et Humanisme (Liège)
Technique et Science Aéronautiques (Paris)
Tecnica e Industria (Buenos Aires)
Tecnica Metalúrgica (Barcelona)
Teknisk Tidskrift (Stockholm)
Teknisk Ukeblad (Oslo)
Tidsskrift for Kjemi, Bergvesen og Metallurgi (Oslo)
Times Review of Industry (London)
Tin (London)
Tin Research Institute (Greenford, Mddx.)
Publications
Tin and Its Uses
Tisco Review (Calcutta)
Tôhoku University (Sendai)
Science Reports of the Research Institutes
Trieste Universita, Facolta di Scienze e d'Ingenieria (Trieste)
Publicazioni

United Engineering and Foundry Company (Pittsburgh)
United Effort
Universidad Nacional de La Plata. Facultad de Ciencias Químicas (La Plata, Argentine)
Contribucions
Upsala University (Upsala)
Bulletin of Geological Institute
Usine Nouvelle (Paris)

Värmländska Bergsmannaföreningens Annaler (Filipstad, Sweden)
Verein deutscher Ingenieure (Düsseldorf)
Zeitschrift
Verkstäderna (Stockholm)

Wagner Free Institute of Science (Philadelphia)
Bulletin
Waste Trade World (London)
Welder (Waltham Cross, Herts.)
Welding (London)
Welding Journal (New York)
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Werkstatt und Betrieb (Munich)
Werkstoff und Korrosion (Mannheim)
West of Scotland Iron and Steel Institute (Glasgow)
Journal
Wire Industry (London)
Wire and Wire Products (Stamford, Conn.)
Wisconsin University, Engineering Experiment Station (Madison, Wis.)
Bulletin

Zeitschrift für Erzbergbau und Metallhüttenwesen (Stuttgart)
Zeitschrift für Metallkunde (Stuttgart)
Zinc Alloy Die Casters Association (Oxford)
Miscellaneous Publications
Zinc Bulletin (Oxford)
Zinc Development Association (Oxford)
Abstracts

ABSTRACTS

MINERAL RESOURCES

Iron Ore Resources and Open-Cast Operations in the Midland Orefield. J. R. Menzies-Wilson. (Journal of The Iron and Steel Institute, 1950, vol. 165, June, pp. 129–137). An attempt has been made to indicate the main problems to be overcome in the future working of Northampton Sand Ironstone and, so far as Britain is concerned, it is almost certain that future developments in the production of ore will occur almost entirely in this bed. In common with other iron ores, the cost of producing home ore is bound to increase with its decreasing accessibility and the need for much greater capital expenditure on machinery and equipment.

Reference has been made to the increasing realization that the natural resources of the world are not unlimited. In regard to ironstone supplies the major problems of the future are: (1) The need to determine the location of hidden deposits, involving large-scale exploration, and (2) the ever-increasing cost of recovering less accessible deposits. Whilst the total supply, based on present consumption, is ample for a long time, it may soon become difficult to maintain the rate of discovery abreast of requirements. This problem will be intensified if the world production of steel is doubled in the next half century.

So far as this country is concerned, there is reasonably accurate knowledge of the reserves, but although the tonnages available are quite substantial they are not by any means unlimited. Prudence dictates that for the sake of succeeding generations, every effort should be made to utilize them wisely without waste, as they are an irreplaceable asset.

Wolfram Deposits in France. V. Charrin. (Génie Civil, 1950, vol. 127, Mar. 15, pp. 110–112). Wolfram exists in France as a manganiferous tungstate of iron, frequently associated with tin in granulitic rock. The main deposits are in the Central Plateau and in Britanny. Present production is 50 tons/month. Seven important deposits and some lesser-known ones are described.—R. S.

Coal Mining in Spain. Important Carboniferous Regions. (Boletin Minero e Industrial, 1950, vol. 29, Feb., pp. 69–83). [In Spanish]. The article describes the coal deposits of Asturias and Leon and gives analyses of the three types of Spanish coal: Pit coal, anthracite, and lignite. Details of wages, prices, and transport are given. Import figures for coal from Germany, England, U.S.A., South Africa, and Belgium are surveyed.—R. S.

The Metallurgical and Mining Industries of Portugal. F. Mota. (Metalurgia y Electricidad, 1950, vol. 14, Feb., pp. 35–39). [In Spanish]. The author first discusses the geology of Portugal and briefly surveys the history of mining in that country. He then describes the present position of mineral production, giving output figures for 1940. The approach to his subject is mainly statistical.—R. S.

The Titaniferous Iron-Ore Deposit of Taberg in the South of Sweden. S. Hjelmqvist. (Sveriges Geologiska Undersökning, 1950, Series C, No. 512). [In English]. The iron-ore mountain Taberg is about 8 miles SSW. from the southern shore of lake Vättern. The ore-bearing rock is connected with an occurrence of hyperite, the northern part of which is almost exclusively made up of magnetite–olivinite. An account of the author's survey and its results is given.

R. A. R.

The Rektor Ore Body at Kiruna. P. Geijer. (Sveriges Geologiska Undersökning, 1950, Series C, No. 514). [In English]. The Rektor iron ore body, on the eastern slope of the mountain Luossavaara at Kiruna was discovered in 1887. In 1918, the author investigated the possibilities of producing apatite for fertilizers; but there was then no suitable concentration process for such fine-grained raw material. From 1925 to 1930 and from 1936 to 1939 a total of 431,601 metric tons was produced. When large quantities were mined the phosphorus content was about 5%, and the iron about 36%. An efficient flotation process has since been worked out, and from 1942 to 1946 about 1·3 million tons have been mined. The geology of this body is described.—R. A. R.

Future Ore Supplies. J. C. Munson. (Iron and Steel Engineer, 1950, vol. 27, Feb., pp. 103–105). The serious problem of high-grade iron ore shortage confronting the iron and steel industry in the United States is described. A brief account is given of the exploratory parties sent out by United States Steel Corp. to all parts of the world. The large Venezuelan deposits are described and the problem of beneficiating the low-grade taconite of the Mesabi Range is discussed. The

choice between investing large sums in developing foreign ore deposits or in beneficiating processes at home is given consideration.—M. D. J. B.

Present and Prospective Sources of Supply of Steelmaking Raw Materials. C. C. Henningen and R. W. Braund. (American Iron and Steel Institute, May, 1950, Preprint). The present position and prospects regarding the supply of limestone, coal, and iron ore for the United States steel industry are discussed. The Southern district has adequate limestone and coal for a great many years' operation; the quality of the iron ore reserves limits any great expansion, but imports will undoubtedly correct this. The Western section should have adequate limestone and ore to meet requirements for a considerable time, whereas coal will be a limiting factor. In the Great Lakes, Pittsburgh, Youngstown, and Ohio Valley districts there will be sufficient raw materials, when the projects now in the engineering stages have been completed, to support the continued demands of the steel industry in these areas. The supply of iron ore will be later augmented by concentration methods, and by exploiting the great deposits in Labrador and Venezuela.—R. A. R.

ORES—MINING AND TREATMENT

Styrian Iron Ore Production Increasing. J. Oberegger. (Steel, 1950, vol. 126, Feb. 6, pp. 102–104). At the Styrian mine in Austria, Marshall Aid has made possible the purchase of modern equipment, and the expected output for 1950 is 5½ million tons. Extensive tests on new mining methods such as magazine, stope and block, caving, and funnel are being carried out.—A. M. F.

Study of the Possibilities of Beneficiating Various French Iron Ores. (Publications de l'Institut de Recherches de la Sidérurgie, 1950, Series A, Apr., No. 18). Samples of three ores from Normandy (Soumont) and four from Lorraine (minette) were investigated by the U.S. Bureau of Mines to determine the best methods of beneficiating them. It appeared doubtful whether the Soumont ores could be treated by physical methods; magnetizing roasting seemed to be the process to be used. With the limey Lorraine ores best results were obtained by differential crushing and by flotation; these methods were equally effective, but the crushing produced more fines. Gravimetric methods (classification on the table, the Humphrey spiral, etc.) were not satisfactory. A. E. C.

Modern Trends in the Preparation of Ore and Coal. G. Tarján. (Bányászati és Kohászati Lapok, 1950, vol. 5, Mar.–Apr., pp. 146–166). [In Hungarian]. The modern methods of ore and coal preparation are described. These include the heavy-media process, the cyclone, the Humphrey spiral, and the Martiny pneumatic table. The application of these processes in Hungary is considered and results obtained with some Hungarian coals are given. The Martiny table was developed in Hungary. It is a fluidization process using compressed air, the pulsations of which can be varied between 6000 and 10,000 cycles/min. The results obtained in practice with the Martiny are shown graphically.—E. G.

Magnetic Separation of Minerals. S. Eketorp. (Canadian Metals, 1950, vol. 13, Mar., pp. 6–9, 46, 47). This is a review of principles and machinery for the magnetic separation and concentration of iron ores, other ores, and raw materials. Methods of treatment are considered separately for coarse (down to 6 mesh), medium (6–100 mesh), and fine-grained materials. American and Swedish examples are quoted. E. C.

Examples of the Use of Rotary Kilns in the Iron and Steel Industry. H. Berg. (Norsk Metallurgisk Selskap: Tidsskrift for Kjemi, Bergvesen og Metallurgi, 1950, vol. 10, Apr., pp. 185–191). [In Norwegian]. Two examples of the use of long inclined rotary kilns are described and illustrated: (1) For agglomerating fine iron ore and blast-furnace flue dust, and (2) the simultaneous production of iron and cement clinker. The largest agglomerating kiln made by F. L. Smidth & Co., Copenhagen, was for the Luxemburg iron industry. It is 82 m. long; its largest diameter is 5·6 m., the discharge end being 4 m. in dia. The cement–iron process was developed in Denmark during the 1939–1945 war when it became necessary to use Danish pyrites cinder as a raw material for ironmaking. Manganese was provided by the lean Danish iron ore which is very high in silica but fortunately contains much manganese; coke breeze was used as the reducing agent. To slag off the silica and other impurities in the coke ash, burnt lime was employed. The raw mixture passes through a wet mill, in which the larger lumps are broken down, into a storage silo, thence through a drier and into the kiln in the form of nodules containing 12% moisture; iron scrap and crushed steel turnings are added. The iron ore is reduced as it passes down the kiln and the molten iron with the melted scrap collects in front of a dam or ring near the discharge end, and on this floats the solid slag or cement clinker. The kiln burners are designed to use oil or pulverized coal as desired. The waste gas is used to heat the drier previously mentioned, and under waste-heat boilers. Improvements since 1945 have reduced the cost of production so that the iron competes successfully with imported pig iron.—R. A. R.

FUEL—PREPARATION, PROPERTIES, AND USES

International Research on Flame Radiation. (Iron and Coal Trades Review, 1950, vol. 160, Apr. 28, pp. 965–966). A brief account is given of the research plan and the experimental furnace at the Royal Dutch Steelworks, Ijmuiden, Holland, where an international team is studying radiation from oil flames of a size comparable with those in open-hearth steel furnaces.—R. A. R.

Instruments and Techniques in Industrial Heat-Transfer Research. R. H. Baulk. (Journal of the Institute of Fuel, 1950, vol. 23, Mar., pp. 77–85). Classical studies of the performance of a combustion chamber have, for reasons which are given, been largely empirical, or of a purely theoretical nature based upon a number of simplifying assumptions. Part I deals with the performance of combustion chambers and discusses some of the instruments and techniques which have been used, or are being developed, in an endeavour to elucidate this problem. Part II shows how existing knowledge of the heat-transfer laws can be applied to the design of the smoke tubes of an Economic boiler, and gives charts to facilitate the design.—R. A. R.

Fuel Efficiency in the Steel Industry. (British Iron and Steel Federation Monthly Statistical Bulletin, 1950, vol. 25, Feb., pp. 1–10). The consumption of different fuels by different departments of the iron and steel industry of Great Britain is discussed and it is shown how fuel costs are being attacked by the blast-furnace, coke-oven, melting-shop, and rolling-mill departments.—R. A. R.

Developments in the Production and Use of Energy in Iron and Steel Works. F. Guéry. (Revue Générale de Mécanique, 1950, vol. 34, Apr., pp. 133–138). By-products of iron-making include blast-furnace and coke-oven gases. The efficient use of these gases for the production of the energy required by the works and methods of utilizing the surplus energy produced are discussed. A heat-balance for a typical steelworks is given, and the special factors affecting the production and use of energy in steelworks of the Lorraine Basin are referred to.—R. F. F.

Coal Preparation: Achievements and Possibilities. L. W. Needham. (Journal of the Institute of Fuel, 1950, vol. 23, Mar., pp. 70–77). Progress in coal preparation during the last 20 years is reviewed by reference to the scope and accuracy of the processes now available. The meaning and use of the 'ash error' as one method of expressing efficiency is explained, and a table is given showing how the chief types of process compare as regards accuracy of separation.—R. A. R.

Coal Preparation in Canada. E. Swartzman. (Fourth World Power Conference, London, 1950, Section B1, Paper No. 1). The paper reviews the methods of coal preparation used in the various coal fields of Canada. Of a total production of 49,500,000 short tons of coal available for consumption in Canada in 1948 about 40%, consisting only of bituminous coal, was treated in plants equipped with wet- and dry-cleaning equipment. In Eastern Canada, about 20% of the Nova Scotia output is wet-washed mainly for the production of by-product coke for steelmaking.—R. A. R.

The Problem of Coal Preparation. A. Grounds. (Fourth World Power Conference, London, 1950, Section B1, Paper No. 2). The paper outlines changes in the mining industry which have had considerable effects on the preparation of coal. Mechanization underground has led to the production of a raw coal containing more free dirt and a greater proportion of fine coal than formerly. The tendency in modern preparation plants is to use a combination of different processes to treat the whole run-of-mine coal, using dense-medium

systems, Baum jigs, and froth flotation for the large, small, and fine coal respectively. The advantages of this are explained.—R. A. R.

Preparation of Solid Fuels in French Collieries. J. Belin. (Fourth World Power Conference, London, 1950, Section B1, Paper No. 3). No attempt is made to lay down what criteria should be established to govern the extent of cleaning, but the paper surveys those characteristics of French coals (ash content, screening, and quality) which are specially important in the processes involved. The most generally adopted organization of coal treatment at collieries is described and the layout of future installations is sketched giving indications of their number and capacity.—R. A. R.

Research of " Charbonnages de France " on Improvements in Coal Preparation. R. Cheradame. (Fourth World Power Conference, London, 1950, Section B1, Paper No. 7). Research by Charbonnages de France ranges from the theoretical representation of cleaning operations to the improvement of existing cleaning processes and the invention of new ones. In 1949 France turned from the empirical and often unsatisfactory investigations of coal cleaning to a scientific analysis which furnished valuable information on the choice of process and the improvement of efficiency.

R. A. R.

Preparation of Coals of High Ash Content. F. C. Meyer. (Fourth World Power Conference, London, 1950, Section B1, Paper No. 8). Coal production in the Union of South Africa has risen from 15·9 million tons in 1938 to 23·5 million tons (metric) in 1948. Brief particulars of the coal seams and typical specific-gravity analyses are given. The treatment of coals is described with details of present installations and flow sheets of some of the cleaning plants. Future trends are pointed out.—R. A. R.

The Mechanical Preparation of Coal and Its Relationship to the Power Industry. T. Laskowski. (Fourth World Power Conference, London, 1950, Section B1, Paper No. 10). It is shown that with the development of the chemical treatment of coal, the supply of fuel will decrease and this will compel power producers to confine themselves to the use of non-caking flame coals and lean coals. The objects of mechanical coal preparation are discussed and the part played by the power supply industry in achieving them is shown.

R. A. R.

The Preparation and Utilization of Victorian Brown Coal. F. H. Roberts. (Fourth World Power Conference, London. 1950, Section B2, Paper No. 1). Although restricted to a small area, the brown coal deposits of Victoria form the greater part, by weight, of the coal resources of Australia. At Loy Yang, near Traralgon, the seam is 803 ft. thick, below 57 ft. of overburden. Over 6,000,000 tons/annum are mined and production is rapidly increasing. The high moisture content (up to 69%) necessitates the employment of special equipment. This equipment and the technique adopted by the State Electricity Commission of Victoria are described and tables of typical test results are given.—R. A. R.

The Preparation and Utilization of Low-Grade Fuels. I—Preparation and Improvement of Brown Coal and Lignite in Czechoslovakia. B. G. Šimek. **II—Utilization of Low-Grade Fuels, in Particular Lignite, as a Source of Energy.** J. Mejstřík. (Fourth World Power Conference, London, 1950, Section B2, Paper No. 2). In Part I the utilization of brown coal and lignite for power production in Czechoslovakia is shown to be highly developed. The cleaning, washing, drying, and briquetting processes developed in Czechoslovakia are referred to. A proposal is made for the petrographic classification of brown coals and lignites. In Part II the difficulties in obtaining efficient combustion of brown coal and lignite are pointed out and two methods of raising the efficiency are discussed in detail; these are the introduction of ignition from below and the pre-drying of the fuel by flue gases from the boilers.—R. A. R.

High-Sulfur Pittsburgh Coal: Upgrading in Southwestern Pennsylvania and Northern West Virginia. T. Fraser, W. L. Crentz, and A. L. Bailey. (United States Bureau of Mines, 1950, Bulletin 483). The report deals with methods of preparing the high-sulphur coal from southwestern Pennsylvania and northern West Virginia to bring it up to metallurgical standards.—R. A. R.

Washing Small Coal. The ACCO Automatic Wash Box. (Iron and Coal Trades Review, 1950, vol. 160, Mar. 3, pp. 487–489). An illustrated description is given of the ACCO (Automatic Coal Cleaning Co. Ltd.) automatic small-coal wash box, operated by compressed air. A box of this design is in use at the Margaret washery, operated by the Durham Division of the National Coal Board, which deals with 90 tons/hr. of raw coal (— 2 in. size). The box operates on the Baum principle, in that water in the box is agitated by the admission of air pressure, and in place of the normal perforated grid plate it has a special grid supporting a layer of feldspar cubes. Shale and other heavy products are drawn through the feldspar and fall to the bottom of the wash box.—J. C. R.

Coking at Coedely. (Iron and Coal Trades Review, 1950, vol. 160, Apr. 14, pp. 860–863). An illustrated description is given of the recently completed extensions to coke ovens at Coedely in the South Western Division of the National Coal Board. The first extension comprises two 10-oven batteries of the Coppée under-fired, regenerative type, each oven being 34 ft. 1½ in. long × 8 ft. 6 in. with a mean width of 21 in. A hard large-sized coke for foundry purposes is produced.—R. A. R.

New Coke Ovens at Consett. (Coke and Gas, 1950, vol. 12, Apr., pp. 119–126). The coking plant of the Consett Iron Co., Ltd., has recently been extended by the addition of two batteries each of 27 Woodall-Duckham Becker Combination Underjet ovens, each oven being 42 ft. 4½ in. long, 14 ft. high with an average width of 18 in. This installation and the new by-product plant are described and illustrated.—R. A. R.

Modern Coke Ovens and By-Products Recovery. Installation of W-D Becker Coke Ovens and By-Products Recovery Plant at the Fell Works of the Consett Iron Company, Limited. (Iron and Coal Trades Review, 1950, vol. 160, Mar. 24, pp. 665–679). A detailed description, with numerous coloured illustrations, is presented of the new coke-oven battery and by-product recovery plant of the Consett Iron Co., Ltd. There are two separate batteries, each of 27 ovens of the W-D. Becker combination underjet type with a capacity of 826 cu. ft. The batteries are designed to carbonize each day 1200 tons of coal containing 7% moisture.—J. C. R.

The Size and Location of Coke Oven Plants. R. J. Barritt. (Year-Book of the Coke Oven Managers' Association, 1950, pp. 110–124). The location of steelworks coke ovens will continue to be decided by ore supply considerations; for works importing ores the plants will be near the coast and not too far from suitable coals and limestone; works using inland ores will be near the ore beds of Lincolnshire or Northampton. The economic size of a coke-oven battery is settled by the performance of one or more sets of oven machines. The slowest machine is the ram leveller, with a minimum time cycle of about 15 min., which can serve 90 to 100 ovens per day. With an oven charge of 16 tons of wet coal, the limiting size of the battery for one ram is about 1500 tons/day. The influence of coke ovens on the collieries, the use of froth flotation coal in ovens, and firing ovens with producer gas are also discussed.—R. A. R.

Measured Load Controls Yield of By-Product Coke Oven. P. M. Pinckard. (Steel, 1950, vol. 126, Feb. 20, pp. 96, 99). In a new type of coke oven, pressure, volume, and temperature are controlled by means of circulation gas introduced into the oven free space. This, together with flue design, prevents the intrusion of hot flue gas and ensures good sealing of the brick joints.—A. M. F.

Studies in the Plastic Properties of Coal as Related to Coal Carbonization. C. C. Russell. (Proceedings of the American Gas Association, 1949, pp. 372–389). The essential elements of the Gieseler plastometer and the movable wall oven used by Koppers Company, Inc., are described, and results obtained with them in studies of the plastic properties of coal are discussed. Samples of coal, oxidized at 105° C. for progressively increasing lengths of time, tested in the plastometer, lost 76% of their fluidity after only 17 hr. oxidation, and lost all fluidity after 244 hr. of oxidation. As the rank of high-volatile coals increases the maximum fluidity also increases, but throughout this change in rank the pressure developed remains low. The maximum fluidities and the pressures exerted decrease and increase respectively as the rank rises through the medium into the high volatile group. A wide temperature range of plasticity at constant rate of coking gives thick plastic seams, and an increase in the rate

of coking at constant range of plasticity results in thinner plastic layers.—R. A. R.

Laboratory Assays for the Selection of Coking Coals. R. A. Mott. (Year-Book of the Coke Oven Managers' Association, 1950, pp. 193–208). Methods of assessing the value of coking coals are discussed. The relationship between 1½-in. shatter index of coke and calorific value of pure coal for different volatile matter is shown for coals from the principal coalfields. The agglutinating value of coal is only of interest at the extremes of the band of coals used for coke making (*i.e.*, low-rank high-volatile and high-rank low-volatile coals). Possible sources of error when determining the British Standard crucible swelling number are pointed out. The Gray-King assay is a complicated test, particularly for strongly swelling coals, and all the information given by it can be much more easily obtained by the B.S. crucible swelling test. The value of tests for determining the by-product yields from coal is considered.—R. A. R.

Composition of Coal, and the Influence of Some Constituents on Carbonization. E. Borras Brucart. (Dyna, 1950, vol. 25, Apr., pp. 154–159). [In Spanish]. The article summarizes present-day knowledge and covers the petrographic constituents, chemical constituents (Gruner and Seyler classifications), and ash content of coal.

A table of the classification of coals according to M. E. Cassan is given.—R. S.

Production of High-Quality Metallurgical Coke from Low-Grade Coking Coals. J. Sabatier. (Génie Civil, 1950, vol. 127, Mar. 15, pp. 104–107). The lack of good coking coals for the reduction of Lorraine iron ores has focused attention on the need to produce high-quality metallurgical coke from the poor coking-quality Lorraine coals. The required characteristics of a good metallurgical coke and French methods of evaluating coke quality are discussed. According to French standards, the classification of coals is determined by the percentage of volatile matter (v.m.) and the swelling index. The three broad classes of Lorraine coal are : (1) 30–40% v.m. with a swelling index of 4·5–9 (it fuses and swells) ; (2) 35–42% v.m. (it fuses but does not swell) ; and (3) 37–44% v.m. (non-swelling).

In order to overcome the difficulties of producing coke from these coals by the classic coking methods, two solutions have been suggested : (1) Adding to the Lorraine coals a certain proportion of bituminous coal possessing excellent fusibility and good swelling properties ; and (2) regulating coking conditions to accentuate the tendency to swelling (by heaping the charges to confer as high an initial density as possible).

Much of the research was carried out at the Thionville coke ovens of the Longwy Company with a view to discovering what proportion of Lorraine coal could be mixed with suitable fusible coals in the classic coking methods. Details of the results of these trials are given. Up to 65% of Lorraine coal could be used. Coking trials with dry coals (37–44 v.m. and a swelling index of 0–1·5), and semi-coke (Carbolux) are described.—R. S.

TEMPERATURE MEASUREMENT AND CONTROL

Calibration of Industrial Pyrometers. A. A. Arantes. (Boletim da Associação Brasileira de Metais, 1948, vol. 4, Jan., pp. 74–94). [In Portuguese]. The method of calibrating industrial pyrometers which is here described is that of the Heat-Treatment Department of the Institute of Technological Research in São Paulo. Details are given of the checking of the measuring apparatus, of the e.m.f. of the thermocouple at various temperatures and of the pyrometer itself. Tables of temperatures corresponding to the e.m.f. of various thermocouples and similar tables for Leeds and Northrup couples are given.—R. S.

Control Systems for Slot or Batch Type Steel Forging Furnaces. (Gas Heat in Industry, 1950, vol. 13, July, pp. 313–314). A brief description is given of the Electronik Limited Throttlor Potentiometer Controller for recording the temperature of forging furnaces and controlling it by adjusting the gas supply to the burners.—R. A. R.

Application of Immersion Pyrometers in French Steelworks. G. Husson and P. Rodicq. (Société Française de Métallurgie, Oct. 5, 1949 : Revue de Métallurgie, Mémoires, 1950, vol. 47, June, pp. 477–484). A very brief mention of the immersion pyrometer is followed by short descriptions of three recording instruments used in France—the Tinsley, the Convertisseur Cug II of the Compagnie des Compteurs, and the Speedomax ; finally some results obtained with these instruments in French steelworks are presented and discussed.—A. E. C.

Radiation Pyrometer for Lower Temperatures. S. Tour. (Iron Age, 1950, vol. 165, May 18, pp. 90–93). The author describes a radiation pyrometer using a thermistor bolometer developed for measuring tinplate temperatures between 180° F. and 400° F. Measurements can be taken as close as 18 in. from the heated strip and the accuracy is stated to be as high as ± 20° F. at 190° F. and ± 5° F. at 360° F.

A. M. F.

Measuring the Temperature of Basic Pig Iron. T. Kootz. (Stahl und Eisen, 1950, vol. 70, Mar. 2, pp. 186–192). It is shown that the radiation factor for molten pig iron is to a large extent independent of the temperature, and amounts to 0·5. A silicate covering radiates 'blacker' when the radiation factor is between 0·6 and 0·7. When determining the temperature of clean molten basic iron with optical measurements in the red, 80° C. must be added (or 55° C. when there is an oxide coating) to obtain the true temperature. The loss of temperature between blast-furnace and mixer has been studied ; the greatest loss is by the heat given up to the brickwork of the ladle.—R. A. R.

REFRACTORY MATERIALS

Natural and Synthetically Produced Magnesite for the Steel-Making Industry. F. Harders and H. Grewe. (Stahl und Eisen, 1950, vol. 70, Feb. 16, pp. 134–145). The supply and requirements of magnesite refractories by the German steel and other industries are considered and methods of making bricks from natural and synthetic magnesite are described ; the economics of the processes are compared.—R. A. R.

The Cracking of Silica Products during Manufacture. T. R. Lynam and A. Nicholson. (Transactions of the British Ceramic Society, 1950, vol. 49, Apr., pp. 141–157). A survey of the probable causes of cracking of silica bricks and shapes during manufacture has shown that the major proportion of cracking is due to inefficient or insufficient drying, or both. Other contributory causes in order of significance are complexity of shape, α–β quartz change, and grading and cooling. The type of raw material has also been found to be of major importance. The crystal size and type of impurity control the rate of inversion and subsequent cracking. Mechanical faults such as press and ramming laminations have not been included. It was not found possible to associate a specific cause with a particular type of crack.

The System Gehlenite–Spinel. R. W. Nurse and N. Stutterheim. (Journal of The Iron and Steel Institute, 1950, vol. 165, June, pp. 137–138). The paper describes experimental work on the binary system gehlenite–spinel, and discusses its significance in the quaternary system CaO–MgO–Al_2O_3–SiO_2.

Nomograms for Apparent Density and Porosity. A. H. B. Cross and P. F. Young. (Transactions of the British Ceramic Society, 1950, vol. 49, May, pp. 191–201). The construction of two charts is described. The first is a 'Z' type alignment chart suitable for determining apparent density from the weight of the dry test piece in air (W_A) and its weight soaked in water (W_B). It measures 20 × 17 in. and results obtained from it are within 0·003 of the calculated values. The second is a gradient-type chart which solves the usual porosity equation from ($W_C - W_A$) and ($W_C - W_B$). It measures 12 × 8 in. and results are reproducible to within 0·1% of the calculated value. A suggested layout for direct recording of all individual weighings to facilitate the necessary subtractions is included. The required accuracy of individual weighings is discussed.

The Refractory Properties of Alunite. I—High-Alumina Refractories, and the Genesis, Occurrence and Uses of Alunite. II—Effects of Heat on Alunite. J. O. Knížek and H. Fetter. (Transactions of the British Ceramic Society, 1950, vol. 49, May, pp. 202–249). This report deals with some aspects of alunite for the manufacture of high alumina refractories as a possible substitute for diaspore and bauxite. Part I deals with the composition, genesis, occurrence, and up-to-date use of the mineral alunite, the deposits in Mexico being discussed in detail. Part II deals with the possibility of converting alunite into a stabilized material suitable for the manufacture of high-alumina refractories. The investigation on the thermal behaviour of the mineral was carried out in two stages. The first stage was to render alunite soluble by

heating at temperatures below 1050° C. and the other dealt with the physical and mineralogical changes with temperatures of up to 1600° C.—R. F. F.

Recent Developments in High-Temperature Refractory Material. A. E. Dodd. (Journal of the Institute of Fuel, 1950, vol. 23, May, pp. 144–147). The author summarizes the results of investigations during the last ten years on the properties of silica, sillimanite, and basic insulating refractories, and on fused magnesia, fused alumina, zirconia, zircon, and beryllia.—R. A. R.

The Effect of Hydrocarbon Gases on Refractory Materials. IX—The Composition of the Iron Spots in the Firebrick Specimens and of the Carbon Spots and Deposits Formed by Methane and Carbon Monoxide. E. Rowden. (Transactions of the British Ceramic Society, 1950, vol. 49, Apr., pp. 172–182). X-ray photographs of the original iron spots in the bricks have shown that for firebricks which are readily attacked, the spots, which are magnetic, mainly consist of ferric oxide with a little magnetite. For a specimen that resists attack, the photographs of the iron spots (which are dark brown, fused into the surrounding brickwork and non-magnetic) have shown mainly brick (mullite and cristobalite); patterns of the iron compounds were practically indiscernible, probably due to their being present in the glass phase, but there might have been traces of hercynite ($FeO.Al_2O_3$) and perhaps fayalite ($2FeO.SiO_2$). Chemical analyses have indicated that the black soot-like deposits and carbon spots produced by the action of methane at the iron spots of some firebricks consist of a mixture of carbon, brick dust, and either metallic iron or iron carbide. The deposits were strongly magnetic throughout. X-ray photographs of the deposits or spots formed at 700° C. have shown metallic iron only to be present admixed with graphite and brick dust; whilst at 880–900° C. all the iron was in the form of iron carbide, Fe_3C. The photographs have not shown the presence of any of the iron oxides FeO, Fe_3O_4, or Fe_2O_3. On the other hand, with carbon monoxide attack at 450° C., X-ray photographs of carbon spots from different specimens have shown the presence mainly of magnetite (Fe_3O_4) with some iron carbide (Fe_3C), very small graphite crystals and a little brick dust. In one case the photographs showed the iron to be present only as iron carbide Fe_3C. In all the above samples it is thought that amorphous carbon was also present.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Preparation of the Materials Used in Blast-Furnace Operation. A. Klaus. (Bányászati és Kohászati Lapok, 1950, vol. 5, Feb.–Mar., pp. 184–193). [In Hungarian]. The methods of preparing the ore, coke and lime, and the treatment of the blast for blast-furnaces are reviewed. Air drying is recommended to obtain more uniform operation. The author also recommends use of oxygen-enriched blast in Hungary and briefly describes the various methods of ore preparation. In Diosgyör a tunnel furnace of the Gröndal type has been built for preparation of 'red slimes' according to a Hungarian method developed by Visnyovszky and Bejna; pulverized ore is mixed with this material during the process. In the discussion B. Vécsei gave results of experiments on Hungarian spathic iron ore and pisolitic bauxite, the object of which was to recover the barium in these ores. By using an extremely fine screen about half of the barium could be recovered as a fine powder containing about 90% barium. A combination of this method with magnetizing roasting is likely to prove successful.

P. Pilter, quoting from Russian literature, mentions that 40 million tons of iron ore will be used in the U.S.S.R. in 1950 and about 40% of this will be of a size less than 10 mm., so that the proportion of sintered ore in the charge has been raised from 20% to 38%. The Dwight-Lloyd machine with a suction area of 75 sq. m. and a capacity of 2000 tons/day is used as standard equipment. Several of these machines have been installed and this has increased the total output of the blast-furnaces in the U.S.S.R. by an amount equal to the output of seven 1000-cu. m. blast-furnaces. To ensure maximum uniformity of the charges, the ores are mixed so that the composition does not vary by more than $\pm 0{\cdot}5\%$. This increased the output by 4–5% and reduced the coke consumption by 2–3%.—E. G.

The Quality of Coke for Blast Furnaces. T. Sanderson (Year-Book of the Coke Oven Managers' Association, 1950, pp. 237–243). Testing the physical properties of coke, and the relation between the test results and blast-furnace operation are discussed. Shatter test data do not correlate with furnace results because coke is only part of the burden. The same shatter index does not always define the same quality of coke; an inherent weakness of this test is that it is carried out on pieces plus 2 in. in size, whereas the coke charged to the furnace may consist of between 40 and 80% of the plus 2 in. fraction. Results obtained at the Workington blast-furnaces with coke of different shatter indices carbonized at different rates are cited; these emphasized the overriding influence of coal quality on the type of coke produced and the beneficial effect of a coke with a reduced minus $\frac{1}{2}$-in. shatter index on a furnace which was driving badly.—R. A. R.

The Use of Coke in Blast Furnaces. T. Sanderson and D. R. Wattleworth. (Journal of the Institute of Fuel, 1950, vol. 23, May, pp. 115–120). An attempt is made, first, to show that coke does more in the blast-furnace than provide the source of heat and reduction, and, secondly, to assess the physical properties of coke in relation to its use in the furnace. Rice's formula is used to determine blast-furnace capacity, and a new coke-quality index is given. The authors have improved the quality of their coke and the benefit exceeded the anticipated value owing to indirect effects; furnace output was increased by 22%, but the changes adopted resulted in greater susceptibility to quite minor variations in raw-material quality, and the maintenance of output and quality of iron called for great skill by the operators.—R. A. R.

The Metallurgy of the Blast-Furnace. T. Kootz and W. Oelsen. (Archiv für das Eisenhüttenwesen, 1950, vol. 21, Mar.–Apr., pp. 77–88). The laws governing the relationship between the compositions of the iron and the slag have been investigated for a large range of pig irons and the results applied to a study of the reduction processes in the furnace. A careful evaluation of the analyses, especially the iron in the slag and the silicon and sulphur contents, shows that there is good correlation between the iron and slag compositions when Oelsen's proposal that the manganese and sulphur have been reduced by the silicon is applied. The two reaction factors $\{(Mn) \times \sqrt{[Si]}\}/[Mn]$ and $(S)/\{[S] \times \sqrt{[Si]}\}$ have approximately the same values in relation to the slag basicity for all kinds of pig iron when the MnO_2 content of the slag is counted as basic. These relationships are only valid for desulphurization as long as the desulphurization in the blast-furnace proceeds with the formation of CaS. The reduction in a furnace making basic iron was studied during the blowing-in. The coke carburizes the iron before either the sulphur or the nitrogen. Carburizing takes place as the acid portions of the burden become liquid at about 1100–1350° C. and is checked more and more with increasing depth of the first molten slag. The silicon is reduced first out of this slag, mostly in the region above the tuyeres. Before becoming carburized, the iron takes up more nitrogen than it can hold in solution in its final composition. As it carburizes, the nitrogen is driven out of the iron, particularly while the silicon reduction is going on. A higher temperature in the furnace improves the reducing capacity of the silicon and promotes the reduction by manganese and the desulphurization.—R. A. R.

Turbo-Blower Control. H. Ziebolz. (Iron and Steel Engineer, 1950, vol. 27, Mar., pp. 107–114). The general principles of blowers are briefly discussed. The author then examines the characteristics of blowers and shows curves for pumping limit and blower characteristics, and how these can be modified by introducing a power wheel into the blower intake and multiple diffuser blades. Regulators are next discussed in some detail, as well as master controllers for use when more than one blower is operating on the same line. 'Anti-pumping' governors and the problem of speed control are also examined.—M. D. J. B.

The Measurement of Stockline Contours on Driving Blast-Furnaces. E. W. Voice. (Journal of The Iron and Steel Institute, 1950, vol. 166, Sept., p. 84). Radar techniques have been developed to obtain a pictorial display of the stockline contour of a driving blast-furnace. To obtain the low-velocity radar-type pulses, sound waves instead of electromagnetic waves had to be used, the system was therefore called 'Pulsed Sondar.' Subsequent work has shown

that magnetostriction transmitters and receivers may be more suitable than a sparking plug and crystal microphones, for use in a blast-furnace.—R. A. R.

The Reduction of Lump Ores. R. Wild and H. L. Saunders. (Journal of The Iron and Steel Institute, 1950, vol. 165, June, pp. 198–214). This paper deals with the overall rate of heat transfer to the centre of ore lumps and the penetration of gaseous reduction. The effect of various factors upon the rate of heat transfer has been assessed, and the temperature lag at the centre of lumps heated at a uniform rate is related to their size. Specimens of a wide range of ores have been subjected to reduction by blast-furnace gas under standardized conditions and subsequently the oxygen gradient from the surface to the centre has been found by chemical analysis. The extent of the penetration of reduction has been related to the porosity of the ore which is, in general, the factor limiting reduction within the lump.

DIRECT PROCESSES

Iron Without the Blast Furnace. S. Eketorp. (Canadian Metals, 1950, vol. 13, Feb., pp. 6–9, 48). The economics of the Wiberg-Söderfors, Kalling, and Höganäs processes of making sponge iron are discussed and compared with those of the blast-furnace. Wiberg-Söderfors furnaces are now being built in units to produce 20,000 tons/annum. Suggestions for increased mechanization of the Höganäs process, with the intention of doing away with the clay crucibles, are made. It is important to consider sponge iron not merely as a raw material to replace scrap, but to take into account the whole picture of cost and quality of steel from ore to finished ingot. R. A. R.

Iron Making in Scandinavia. (Teknisk Ukeblad, 1950, vol. 97, Feb. 9, pp. 93–96). [In Norwegian]. The paper summarizes an address by M. Tigerschiöld at Trondheim on November 11, 1949, entitled, " Different Methods of Exploiting Scandinavia's Iron Ore Resources " in which he disapproved of the plan to construct an iron and steel works at Mo i Rana, and described Swedish methods of making sponge iron.—R. A. R.

PRODUCTION OF STEEL

Chemistry in Iron and Steel Making. F. D. Richardson. (Iron and Coal Trades Review, 1950, vol. 160, Apr. 28, pp. 949–956). The author describes the functions of the Chemistry Department of the British Iron and Steel Research Association, and outlines the work being done to collect data on the thermodynamic aspects of iron and steel making processes. A special effort is being made to represent the thermodynamics pictorially, so that the findings can be readily appreciated and used with little or no further calculation. On the experimental side a major effort has been devoted to research on important metal sulphides and on solutions of sulphur in liquid steel and slag. The atomic nature of liquid slags is being examined by studies of their electrical conductivity and electrolysis. The work on refractories, especially the basic roof for open-hearth furnaces is outlined.—R. A. R.

The Layout of Iron and Steel Works. H. H. Mardon. (Iron and Coal Trades Review, 1950, vol. 160, Mar. 31, pp. 725–733). The factors governing the site and layout of iron and steel works are considered with numerous examples and diagrams.—R. A. R.

Production in the Converter, Characteristics and Use of FAH Cast Irons. M. Mallevialle. (Société Française de Métallurgie, Oct. 5, 1949 : Revue de Métallurgie, Mémoires, 1950, vol. 47, June, pp. 465–471). The refined irons known as FAH cast irons are synthetic irons produced by recarburization of molten steel in the basic converter ; they were originally made at the Hagondange Steelworks. Two converters are used, one to convert pig iron into steel and the other for the recarburization of this steel. The following grades, the properties of which are described, are produced : (*a*) Steely cast iron, for making heavily stressed parts ; (*b*) grey hematite irons, for parts subjected to high temperatures followed by rapid cooling ; (*c*) cast irons for malleablizing ; (*d*) semi-phosphoric cast irons, for use where great fluidity is required ; (*e*) hematite irons for use in open-hearth refining ; and (*f*) special cast irons.—A. E. C.

Changes in the Concentration of Basic-Bessemer Steel on Prolonged Holding after the Blow. W. Geller. (Stahl und Eisen, 1950, vol. 70, Feb. 16, pp. 145–146). Samples of steel and slag were taken from a 20-ton converter immediately after turning down and about 10 and 20 min. later, in order to study whether the slag–metal reactions had reached equilibrium. The results for manganese, phosphorus, sulphur, nitrogen, and oxygen indicated that, under the operating conditions prevailing, equilibrium had been practically reached in all cases except when phosphorus was between 0·04 and 0·08% at the end of the blow. If, however, the blow was continued to bring the phosphorus down to 0·02 to 0·03%, then this reaction was also complete.—R. A. R.

Desulphurizing for the Bessemer Process. E. P. Best. (American Society for Metals : Blast Furnace and Steel Plant, 1950, vol. 38, Mar., pp. 314–321). Most of the information in this paper was also given in the author's report entitled " Desulphurizing Cupola-Melted Hot Metal by Ladle Treatment with Alkalis " (*see* Journ. I. and S.I., 1950, vol. 165, July, p. 350).—R. A. R.

Deoxidation with Ferro-Aluminium in the Basic Bessemer Steelworks. J. Klärding and A. Meyer. (Iron and Steel Institute, 1950, Translation Series, No. 404). This is an English translation of a paper issued in 1944 as Confidential Report No. 61 of the Verein deutscher Eisenhüttenleute. (*See* Journ. I. and S.I., 1950, vol. 165, May, p. 107).

Oil Burning Tip-Atomizing Burners in the Open-Hearth Furnace. A. L. Cude and J. R. Hall. (Journal of The Iron and Steel Institute, 1950, vol. 165, Aug., pp. 419–429). Trials have been carried out on a production furnace to compare two types of tip-atomizing burner, designed to give control over atomization and flame shape, with the standard back-end atomizing burner. No significant differences in either furnace performance or fuel consumption were found. In all cases the same oil-flow rates and steam/oil ratios were required for smooth operation. It is suggested that the quantity of steam was the controlling factor in combustion, and that burner design was of minor importance.

Pressure and Flow-Distribution in a Model of a Venturi-Type Open-Hearth Furnace. J. A. Leys and E. T. Leigh. (Journal of The Iron and Steel Institute, 1950, vol. 165, July, pp. 301–306). Measurements have been made, on a 1/24 scale model of a 120-ton open-hearth Venturi furnace, of the pressure losses in the regenerator and uptake systems, the velocity distribution in the air uptakes and in the furnace chamber, and the partition of waste gases at the outgoing end of the furnace. Calculations have also been made of the losses between various points in the furnace, and these are compared with the experimental results. Agreement of observed with calculated pressure-loss factors is good.

Critical Investigation of the Design of Open-Hearth Furnaces. B. Selmeci. (Bányászati és Kohászati Lapok, 1950, vol. 5, Apr., pp. 282–289). [In Hungarian]. The author makes a critical review of the various designs of checker chambers from the point of view of Hungarian requirements. Attention is drawn to the advantage of using vertical chambers and the correct brick shape, and also to the effect of the shape of the furnace on its output. The advantages and disadvantages of the Maerz, Radenthein, and Terni furnaces are discussed and a short description is given of the Venturi furnace end. Such furnace ends have been in experimental use in Hungary and a modification in their design by the author is mentioned.—E. G.

Second Series of Trials with the Oxygen Enrichment of Combustion Air in the Open-Hearth Furnaces at Pompey. G. Husson, P. Bettembourg, and J.-M. Corrèze. (L'Institut de Recherches de la Sidérurgie, Series A, 1950, No. 14, May). The first series of tests with oxygen in the open-hearth furnace was carried out in July, 1947, at Pompey. These tests resulted in a saving of 1 hr. in open-hearth heats (previously 6½ hr.). The first series of tests included only five casts using oxygen, and the present report deals with more prolonged tests in July, 1948.

The first object was to check and complete the 1947 results and the tests were therefore carried out under similar conditions, *i.e.*, flow of fuel oil was increased 10–20% ; oxygen was added at the rate of 600 cu. m./hr. with slight reduction in air flow during charging and the first part of the melting period. Details of furnace design, burners, and instrumentation are given. Operating methods are described, including details of the oxygen feeding. Hourly average outputs and fuel oil consumptions are stated. Costs are discussed on the basis of 1948 prices in francs.

Hourly output was increased 25% and fuel oil consumption reduced by 17% using oxygen in a fuel-oil-fired furnace. A suitable supply of scrap and convenient means of charging must be available.

With silica refractories, the extra expenses incurred by using oxygen at the rate of 25 to 30 cu. m./ton carry a possible risk of cancelling out the savings in fuel and the economy on fixed charges (overheads) as furnace working is accelerated without bringing any considerable improvement in the cost position. A statistical conception of the trials is contained in an appendix.—R. S.

On Speeding Up the Steel Production in Open-Hearth Furnaces. (Hutnické Listy, 1950, vol. 5, Apr., pp. 179–180). [In Czech]. Successful efforts are described in which the total heat time for a charge in an open-hearth furnace at the Třinec Steelworks was reduced from 8 hr. to 3¾ hr.—E. G.

Increased Open-Hearth Production by Improved Charging Methods. R. Tietig, jun. (Iron and Steel Engineer, 1950, vol. 27, Mar., pp. 64–72). The overall problem of open-hearth furnace charging is considered and it is suggested that greater efficiency could be obtained by introducing a number of minor improvements without necessarily resorting to radically new methods. Charging procedure is examined and stress is laid on the importance of timing the charge materials to produce a minimum charge-to-tap time. Factors affecting this time, such as hot metal and pig content, nature of scrap, furnace dimensions, fuel, etc., are discussed. Based on these factors, the author suggests a number of remedies to increase materials availability and speed of charging. Track layout, scrap preparation, charging box and cars, furnace doors, charger cranes, ladles, mixers, locomotives, and, lastly, buildings and crane runways are considered in relation to production. Detailed information is given on siding requirements and scrap baling plant. Operating costs of baling plant and comparative costs of E.O.T. (electric overhead travelling) and bridge cranes as well as productivity figures for E.O.T. and locomotive cranes are also given.—M. D. J. B.

Basic Conditions in the Manufacture of High-Grade Steel with Particular Reference to Conditions in Hungary. V. Zsák. (Bányászati és Kohászati Lapok, 1950, vol. 5, Feb.–Mar., pp. 193–198). [In Hungarian]. The author deals with the influence of the quality of the raw materials, the preparation of the charge, the open-hearth process, the absorption of hydrogen by the melt and its elimination, deoxidation, slag control, tapping, and casting. According to a Russian author, platinum/platinum–rhodium thermocouples in a quartz tube are currently used in the U.S.S.R. for temperature measurements during the melting process, and complete slag analysis is carried out five times for each melting cycle. G. Sailer has investigated the influence of the sulphur content of the heating gas on the sulphur in the steel produced, using producer gas with 10–14 g./cu. m. of sulphur, sulphur-free carburized blast-furnace gas, and a mixed gas containing 5–6 g./cu. m. of sulphur. The first of these three fuels produced steel high in sulphur; there was little difference in the sulphur contents of steels made with the other two fuels.—E. G.

The Desulphurization of Basic Open-Hearth Steel. R. Zoja and P. Raffo. (Metallurgia Italiana, 1950, vol. 42, May, pp. 173–174). A method of desulphurizing the bath prior to oxidation is described; in this the slag of the previous melt is used.—M. D. J. B.

Electricity in the Modern Metallurgical Industry. A. Bruck. (Metalurgia y Electricidad, 1950, vol. 14, Mar., pp. 28–30). [In Spanish]. The rôle of electricity in the metals industry is briefly illustrated by references to the low-shaft electric furnace, electric steelmaking furnaces, heat-treatment furnaces, and resistance reheating furnaces.—R. S.

Consideration of the Economics of the Mass Production of Steel in Electric Furnaces. H. W. McQuaid. (Metallurgia Italiana, 1950, vol. 42, June, pp. 195–200). The comparative costs of manufacturing steel in open-hearth furnaces, in Bessemer converters, and in electric arc furnaces are examined. The author shows how, because of the difficulty of obtaining adequate raw materials for open-hearth furnaces and especially because of the recent improvements in the construction and operation of arc furnaces, it is now possible for electric furnaces to compete successfully with the open-hearth process.

M. D. J. B.

Small Steelworks for Local Markets. H. W. McQuaid. (Metallurgia Italiana, 1950, vol. 42, June, pp. 200–204). Transport adds an appreciable cost to the price of steel. Moreover, the technique of fabrication based on the casting of small ingots of the dimensions of billets gives excellent results and is economical when the ingots are rolled in medium and small mills. The combination of electric arc furnaces for the production of steel and fast modern mills with an annual output of 100,000 tons can compete effectively with the large integrated works. These smaller works can be put up with very modest capital investment.—M. D. J. B.

The Use of the Oxygen Lance in British Electric Furnace Practice. Part I—The Use of Oxygen for the Production of Low-Carbon Alloy Steels other than High-Chrome Steels. T. H. Harris and D. J. O. Brandt. (Journal of The Iron and Steel Institute, 1950, vol. 165, Aug., pp. 399–410). The technique of using the oxygen lance during the boiling-down period in 18-ton and 29-ton electric arc furnaces is described. Typical results obtained on both high-carbon and low-carbon charges are recorded in tables, and graphs are given showing that the rate of carbon removal and the effectiveness of the oxygen lance diminish as the carbon in the bath falls. The effect of oxygen on residual manganese is discussed; data on the possible rise in temperature during oxygen injection and some records of lance life are given. It is concluded that for successful operation a 'specific oxygen input rate' of more than 5 cu. ft./min. per ton of steel must be used.

The Use of the Oxygen Lance in British Electric Furnace Practice. Part II—The Use of the Oxygen Lance in Stainless Steel Production. W. H. Everard and D. J. O. Brandt. (Journal of The Iron and Steel Institute, 1950, vol. 165, Aug., pp. 411–418). The technique of blowing oxygen into the bath of a 4-ton Héroult furnace through a ¾-in. wrought iron tube during the refining period is described and details of carbon reduction and chromium loss are given. The physical chemistry of this process is briefly reviewed and data are set out showing the alteration of composition and temperature during oxygen injection. It is shown that a high initial silicon content of the metal may protect the chromium against oxidation, but may hinder subsequent re-chromizing with ferrosilicon. The log sheet of a typical heat is included.

PRODUCTION OF FERRO-ALLOYS

The "Elkem" Rotating-Hearth Furnace for Electrometallurgical Processes. T. Ellefsen. (Boletim da Associação Brasileira de Metais, 1947, vol. 3, Jan., pp. 175–184). [In Portuguese]. The electric furnace for the production of ferroalloys and calcium carbide, of the "Elkem" rotary-hearth type, prevents the formation of crusts and the sintering of the charge which occur in fixed arc furnaces. The consumption of raw materials per ton of product and the power costs are lower than for the fixed furnace—R. S.

Electric Furnaces in the Metal Industries. G. R. Bashforth. (Metallurgia, 1949, vol. 40, Sept., pp. 249–254; Oct., pp. 304–307). Indirect and direct arc furnaces, and electric reduction furnaces for the manufacture of ferro-alloys are described. It is shown that theoretically the amount of electric power required to melt 1 ton of steel at 1600° C. is 342 kWh. In arc furnaces the distribution of power is approximately 62% to the charge, 9% to electrical losses, 4% to the cooling water, and 25% to radiation losses. By operating two furnaces so that their melting and refining periods are staggered, a much improved load factor is obtained. In the second part of the paper descriptions are given of low- and high-frequency furnaces for melting, and resistance furnaces for heat-treatment.—R. A. R.

Design and Control of Ferroalloy Furnaces. F. V. Andreae. (Transactions of the American Institute of Electrical Engineers, 1950, vol. 69, Part I, pp. 557–562). Three-phase electric furnaces are mainly used in the U.S.A. for making ferro-alloys, some have three electrodes in line, and with others they are placed at the corners of an equilateral triangle. The design and electrical characteristics of the furnace, and the design of bus-bars, flexible connections to electrodes, and electrode holders are discussed. Design equations are presented and the methods of controlling the furnace are explained.—R. A. R.

Titanium in Industry. H. O. Nicolaus. (Zeitschrift des Vereines deutscher Ingenieure, 1950, vol. 92, Mar. 1, pp. 153–160). An account is given of the occurrence of titanium ores in nature, preparation of the ore, production and use of

ferrotitanium, production of pure titanium powder, use of the powder in powder metallurgy, melting and casting titanium in the induction furnace, the properties of pure titanium, and uses of titanium as an alloying element and of titanium carbide, nitride, boride, and silicide in heat-resisting materials. There are 75 references.—R. A. R.

The Ferroalloying Metals. W. H. Dennis. (Mine and Quarry Engineering, 1950, vol. 16, Feb., pp. 45–52). The occurrence of ores containing tungsten, chromium, titanium, and manganese, their concentration, and the preparation of the ferro-alloying materials (including ferrosilicon) used for introducing alloying elements into iron and steel are briefly described.—R. A. R.

FOUNDRY PRACTICE

Production of Grey Iron Castings. R. L. Collier. (Steel, 1950, vol. 126, Jan. 23, pp. 64–76). This is a description of the production of grey iron castings in America. Grey iron foundries use about 10% of all pig iron and about 30% of all iron and steel scrap sold in the open market. Grey iron in recent years has represented about 83% of all ferrous cast material produced.—A. M. F.

Cupola Dust Collection. W. N. Witheridge. (Foundry, 1950, vol. 78, Feb., pp. 84, 198–208; Mar., pp. 88–91, 220–229). The theory and practice of cleaning cupola waste gases are discussed. The advantages of wet-cleaning systems are: (1) Improved collection of finer fractions of insoluble as well as soluble dust; (2) possibility of removing part of the gaseous sulphur from the stack gas; (3) cooling effect of the water on the collector elements; (4) quenching of incandescent particles reduces risk of fire; (5) possibility of using the heated waste water; (6) convenience of hydraulic disposal of the dust; (7) possibility of collecting sediments from several wet collectors in a single dewatering installation; and (8) the abrasive effect of heavy particles is reduced by the lubricating influence of the water. The disadvantages of wet systems include: (1) Need for special pumping equipment; (2) hardness of water may cause choked nozzles; and (3) possibility of corrosion by mist settling in the vicinity, especially in cold weather. Some advantages of dry systems are: (1) Retention of sensible heat in the gas for transfer to the blast in a dry heat-exchanger; and (2) minimum corrosion activity. Some disadvantages are: (1) Equipment must be of materials capable of resisting high temperatures; (2) difficulty of moving dry dust; and (3) inability to reduce the concentration of gaseous sulphur.—R. A. R.

Closed Top System in Cupola Stack Emission Control. J. F. Drake and T. G. Kennard. (American Foundryman, 1950, vol. 17, Feb., pp. 55–57). To prevent pollution of the atmosphere the Renfrow Foundry, Los Angeles, installed a closed-top system and gas cleaners on their cupolas; these are described. The dust in cupola gas is very different from that in blast-furnace gas, the former being much finer, lower in iron, and resistant to wetting. The operation of a closed-top cupola with bell charging presented no unusual difficulties, but the dry dust catcher followed by the washing tower still left 0·55 to 0·70 grains/cu. ft. in the gas, most of this being under 5 microns with the bulk only 1 micron or less. Proposals for additional cleaning are made.—R. A. R.

The Cupola—Its Raw Materials and Operation. B. P. Mulcahy. (Foundry, 1950, vol. 78, Feb., pp. 76, 77, 226–230; Mar., pp. 74–77, 198–202). The five principal factors affecting the quantity and quality of the iron produced in a cupola, *i.e.*, equipment, raw material, fuel, air, and mode of operation are discussed and recommendations on their control are made with a view to producing good iron economically.

R. A. R.

Cupola Practice. A. Guédras. (Métallurgie, 1950, vol. 82, May, pp. 349–353). The author deals with the calculation of the charge and the desulphurizing of the iron by special coke. Reactions in the oxidation and reduction zones are explained. Two detailed examples of charge calculations are given. The author suggests that it is better to desulphurize by using a special coke than to add fluorspar or sodium carbonate. The coking coal may be mixed with two powders, one with a lime base containing fluorspar, potassium, or soda for desulphurizing; the other containing high-silica sand mixed with sodium silicate, potassium silicate, or calcium silicate plus fluorspar to liberate silicon.—R. S.

Added O_2 Improves Cupola Output. E. S. Clark. (Iron Age, 1950, vol. 165, May 5, pp. 96–100). Controlled experiments have been made with oxygen additions in a 48-in. dia. cupola. Results show that metal can be produced at higher temperatures, less coke is needed, total carbon for the same mix is raised, silicon loss and sulphur pick-up reduced, melting rate may be increased, tensile strength of output maintained, fluidity improved, and bridging in the cupola decreased.

A. M. F.

Subcritical Isothermal Graphitization. H. A. Schwartz, J. D. Hedberg, and R. Eriksen. (American Foundrymen's Society, 1950, Preprint No. 2). The authors have studied the rate of secondary graphitization of a white cast iron. The necessity for first determining the conditions of an intermediate stage of graphitization which goes on during the cooling process, is emphasized. This intermediate stage occurs over a short period and graphitization is very rapid. An account is presented of the experimental work carried out.

J. C. R.

Steel Founding. F. A. Martin. (Institute of British Foundrymen: Foundry Trade Journal, 1950, vol. 88, Feb. 16, pp. 167–176). A comparison is presented of various aspects of British and American foundry practice and technique, observed by the British foundry productivity team during their visit to the United States.—J. C. R.

Production of High Alloy Steel Castings. W. H. Worrilow. (Steel, 1950, vol. 126, Feb. 13, pp. 89–96; Feb. 20, pp. 91–94, 102, 105–106). Current operations in high-alloy steel (more than 8% alloying elements) foundries producing heat and corrosion-resistant steels in America are described and a history of the development of the industry is given.—A. M. F.

Production of Steel Castings. W. Briggs. (Steel, 1950, vol. 126, Jan. 30, pp. 60–70; Feb. 6, pp. 90–100). The practice of steel casting, including melting furnaces, patterns, mould preparation, finishing operations, heat-treatment, and inspection current in America is described.—A. M. F.

Fluidity of Steel. J. E. Worthington. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 971: Foundry Trade Journal, 1950, vol. 89, July 27, pp. 87–93). It is now generally agreed that a standard spiral test piece is best for the determination of fluidity, but results differ if the rate of pouring is not accurately controlled. A method of standardizing the rate of pouring is described and some results obtained with it are given; the curves produced all exhibit a characteristic break (a fact only once previously reported). The way in which the fluidity of steel varies with carbon contents is shown. The fluidity of some alloy steels is also given.—R. A. R.

Effect of Liquid Metal Properties on the Casting Fluidity of Alloys. V. Kondic. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 972). The author reviews the data available which relate the properties of a liquid alloy with results obtained in fluidity tests. He discusses how the (*a*) inherent and (*b*) non-inherent properties of liquid metals affect the fluidity; under (*a*) are heat content, viscosity, surface tension, and constitution; under (*b*) are gas content, surface oxide films, and impurities.—R. A. R.

Penetration of Molten Metal into Compacted Sand. T. P. Hoar and D. V. Atterton. (Journal of The Iron and Steel Institute, 1950, vol. 166, Sept., pp. 1–17). The factors influencing metal penetration into compacted sand, with special reference to high-temperature ferrous castings in sand moulds, have been investigated by means of a flexible laboratory apparatus capable of simulating practical conditions of temperature, pressure, metal movement, surface treatment of the mould, and chemical reaction between metal and mould.

It is shown that molten iron, steel, and a number of non-ferrous metals do not wet silica, and that consequently a critical metallostatic pressure, termed the 'penetrating pressure,' must be reached at the metal/sand-compact interface before penetration can occur. For iron and steel at about 1600° C. in contact with sand compacts of average mesh, the penetrating pressure is of the order of 20–60 cm. of Hg, or 35–110 cm. of iron or steel.

Penetrating pressure is proportional to the metal surface tension, and increases with decrease of sand grain size, since this causes a decrease of effective pore radius. The penetrating pressures for iron and steel are reduced by the sand sintering that occurs at steel casting temperatures, since this tends to increase the effective pore radius, but they would be

increased at still higher temperatures where the extensive fusion can close pores. For sand compacts of the same grain-size distribution, differing only in binder content, the penetrating pressure of iron at 1600° C. is nearly proportional to the air-permeability time at 20° C., both properties showing a maximum at an optimum binder content.

The penetrating pressure for iron increases with increasing surface oxidation for metal, owing to the formation of ferrous silicates which partially plug the pores in the sand compact. There is evidence that, under non-oxidizing conditions, the penetrating pressure decreases with increase of carbon content in steel.

Silica mould washes do not greatly influence the penetrating pressure of iron, owing to cracking, but they tend to reduce sand adherence, by localizing the points of penetration. Thick washes so compounded that they melt to slag-like materials can, by filling pores and covering the sand surface with a continuous viscous layer, prevent metal penetration and sand adherence.

Calculations of the rate and extent of penetration, based on known values of metal and slag viscosities and on extrapolated values of the thermal conductivities of compacted sands, show that penetration of either metal or slag occurs in a fraction of a second to the depth of sand heated to the solidification temperature of the penetrating fluid. The depth of penetration is limited by the thermal diffusivity of the sand compact and by the degree of superheat of the penetrating fluid, not by its viscosity.

How to Use Seacoal in Molding Sands. H. L. Campbell. (Iron Age, 1950, vol. 165, May 4, pp. 101–102). Seacoal is a finely ground bituminous coal, and properly blended with facing sand it can be used to improve the surface of castings. Ash, sulphur content, and moisture in the coal must be low. A significant part played by the seacoal is in the formation of a gas cushion.—A. M. F.

Production and Use of Foundry Bonding Clay. (Foundry Trade Journal, 1950, vol. 88, Mar. 2, pp. 223–227). An illustrated account is presented of the production by Albion Pulverising Co. Ltd. of 'Albond,' a kaolinite clay found in Dorset. It is used as a low-percentage addition to natural moulding sands, and examples are given of some of its applications.—J. C. R.

Rationalisation of Sand Preparation. J. F. Goffart. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 975). The characteristics of sands and bonding agents are explained and the requirements of a sand preparation and reclamation plant are discussed. A description is then given of the cycle of operations, units, and layout embodying the author's views of a suitable and rationally designed sand-handling plant.—R. A. R.

The Moulding Materials Applied in Hungary. A. Tóth. (Bányászati és Kohászati Lapok, 1950, vol. 5, Feb.–Mar., pp. 220–228). [In Hungarian]. The Hungarian natural and artificial moulding sands are discussed. Research work is being carried out to produce bentonite and synthetic sand mixtures from Hungarian raw materials.—E. G.

Casting Design as Influenced by Foundry Practice. O. Smalley. (Foundry Trade Journal, 1950, vol. 88, Feb. 9, pp. 153–154). Notes on pattern-making practices are presented, dealing with the construction of patterns and core-boxes, the maintenance of patterns, and casting shrinkage. J. C. R.

How to Use Phenolic Casting Resins for Pattern Coatings. E. J. McAffee. (American Foundryman, 1950, vol. 17, Feb., pp. 27–28). Phenolic casting resins should not be used on metal patterns but are excellent for wood patterns. Coated wood patterns have been used in more than 1000 moulds without refinishing being required. A filler or undercoat is desirable before applying the plastic; shellac should not be used for this. A thinner for the coating mixture consists of equal amounts by weight of ethyl acetate, butyl alcohol, ethyl alcohol, and methyl ethyl ketone.—R. A. R.

Pattern Engineering and Foundry Practice. A. Pirrie. (Canadian Metals, 1950, vol. 13, Mar., pp. 24–27, 49). The need for co-ordinating design and production of castings is illustrated. Stress is laid on providing adequate taper. Errors are discussed in the design of pattern partings and gates, and in size and equipment of flasks.—E. C.

Principles of Gating Design. W. H. Johnson, W. O. Baker, and W. S. Pellini. (American Foundryman, 1950, vol. 17, Apr., pp. 106–113). Factors influencing the flow of molten steel at 3000° F. flowing through different gating systems were studied by Kodachrome cinephotography at 64 frames/sec. Flow through finger gates of different design but all in the same horizontal plane, as well as through stepped gates at 6-in. vertical intervals was investigated. The initial entry of metal into the gating system approaches free fall, but as the system fills, a ferrostatic back pressure is developed and the action approximates that of a pressurized system. Finger gates of special design are required to secure uniform flow. Absorption of momentum is obtained by having pools in the runner, and with less success by bending the runner away from the casting, or with a tapered runner.—R. A. R.

Gating Systems and the Production of Some General-Engineering Castings. W. Collinge. (Institute of British Foundrymen: Foundry Trade Journal, 1950, vol. 88, Feb. 2, pp. 111–118, 122). An illustrated description is presented of the casting of parts of flameproof electric motors and 'Index' automatic machines with particular reference to gating practice.—J. C. R.

Sheet Metal Forms Simplify Molding and Coremaking. H. W. Dietert. (American Foundryman, 1950, vol. 17, Feb., pp. 36–38). The use of tinplate forms to simplify moulding and core-making operations on repetition castings is described with sketches of many examples. Tin forms were developed for casting holes for hinge pins in stove doors and door frames, and their application has extended to produce horizontal holes through sections above or below the parting line. The pattern is recessed, for example, to take the tinplate tube in such a manner that, when the pattern is withdrawn, the tube filled with core sand remains in the mould. On pouring the metal, this tube, being protected by sand on one side, does not melt but becomes permanently welded to the casting. As the sheet-metal forms require dies for their manufacture, the numbers of castings must be sufficient to justify this expense.—R. A. R.

Semi-Permanent Moulds to be Used for Large Castings. (Hutnické Listy, 1950, vol. 5, Apr., pp. 180–181). [In Czech]. The foundry of the Československa Kolben Daněk is introducing an improved method of moulding for large castings to be produced in small numbers. This method consists of making a permanent upper part of the mould whilst the bottom part is moulded in a pit in the usual way. The material for the upper part of the mould consists of 20% clay containing about 25% of particles less than 0·06 mm., 55% of gneiss sand, 1% of organic matter, and 24% water. The dried mixture is very porous. This method is advantageous for moulds for castings having a smooth surface which is not likely to damage the upper part of the mould during the shrinkage period; if there are projecting parts in the casting, cores of softer material have to be used. This method saves labour, sand, and fuel for drying. Several practical examples of the application are described in the paper and the savings obtained in each case are given.—E. G.

New Methods of Casting Metals Promise Great Economy in Manufacture. (Tecnica e Industria, 1950, vol. 28, Feb., p. 170). [In Spanish.] The article briefly describes the American Bacco process of moulding, forging, and coining finished pieces developed by Budds Aero Castings Inc. The secret of the process lies in the uniform application of pressure on all faces of the casting. An account is also given of the Electronicast method of precision-casting with polystyrene moulds developed by Electronicast Inc. This method of electronic casting is similar to the lost-wax process.—R. S.

The Centrifugal Casting of Hollow Steel Ingots of Very Large Dimensions. W. Lückerath. (Stahl und Eisen, 1950, vol. 70, Mar. 16, pp. 209–218). The development of vertical centrifugal casting of hollow ingots from weights of 3 tons in 1933 to 45 tons in 1944, with all its attendant difficulties, is reviewed and illustrated. The experience gained has enabled hollow ingots to be produced of steel with properties superior to those of ingots cast in stationary moulds. The problems arising in the design of a machine capable of revolving 45 tons of molten steel for 8 hr. at a peripheral speed of 100 m.p.h. are discussed.—R. A. R.

Report on Results of Experiments in the Production of Nodular Graphite in Cast Iron Using Alloying Materials Available in Hungary. N. Hajtó. (Bányászati és Kohászati Lapok, 1950, vol. 5, Apr., pp. 268–279). [In Hungarian]. The author has carried out experiments to produce nodular

graphite in cast iron by means of magnesium–aluminium and magnesium–aluminium–silicon additions. The object of the experiments was to investigate the possibility of replacing nickel by cheaper alloying elements obtainable in Hungary. In some experiments calcium was used instead of magnesium. Interesting results were obtained by adding about 0·7% of calcium (as calcium–silicon alloy) to the liquid iron and adding 1% of magnesium (as magnesium–aluminium–silicon–iron alloy) after the calcium had dissolved in the iron. The structures of the various specimens obtained in the experiments are shown on 46 micrographs. The results obtained are useful for planning further experiments, but no conclusions should be drawn from them.—E. G.

Review of the South African Foundry Industry. H. G. Goyns. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 974). The paper deals with the extent and scope of the South African foundry industry, giving particulars of types and number of foundries, tonnages involved, types of casting, plant, laboratories, raw materials, refractories, casting technique, costing, estimating, personnel, and welfare.—R. A. R.

Flow-Line in the Foundry. (Machinist, 1950, vol. 94, Apr. 1, pp. 431–437 ; Apr. 8, pp. 463–466). The new mechanized foundry at the Stoke, Coventry, works of Humber Ltd. is described. The plant produces 180 to 220 tons of grey iron castings per 44-hr. week and uses two continuous casting machines, one for miscellaneous castings and the other for cylinder blocks.—R. F. F.

In the Steel Foundry—6. (B.S.F.A. Log, 1950, Mar., pp. 5–10). An illustrated description is given of the layout, equipment, and operations at the steel foundry of Crofts (Engineers) Ltd., Thornbury, Bradford. This foundry specializes in the production of cast manganese-steel gears up to 16 ft. in dia.—R. A. R.

Mechanized Iron Foundry. (British Engineering, 1950, vol. 32, Mar., pp. 1330–1336). A description, with numerous illustrations, is given of the new fully mechanized foundry of Ruston & Hornsby, Ltd. Attention is directed specially to the conveyor systems. (*See* Journ. I. and S.I., 1950, vol. 165, May, p. 112).—R. A. R.

Gas Burner Production at Stockport. A. G. Thomson. (Foundry Trade Journal, 1950, vol. 88, Feb. 9, pp. 147–149, 151). An illustrated description is presented of the plant of the Storey Foundry Company, Ltd., Stockport, where gas burners are the principal product. A feature of the plant is the synchronization of melting with mould production which has been achieved in the layout by installing a gravity roller track and making adequate provision for mould storage on cross tracks—J. C. R.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Heat Treatment of Steel. S. L. Gertsman. (American Society of Metals : Canadian Metals, 1950, vol. 13, Apr., pp. 9–11, 42, 44, 45). The author describes fundamentals of heat-treatment based on microstructural transformations. The iron/iron-carbide equilibrium diagram is discussed, showing the relationships between ferrite, pearlite, and austenite. Austenitizing is defined and the effects of grain size and solution of carbides on the austenite condition are described. Transformations of austenite are considered and isothermal transformation diagrams explained. Their use is exemplified by reviewing the processes of normalizing, full and isothermal annealing, spheroidizing, and hardening. Internal stresses are discussed, also their relief by hot-quenching methods such as martempering, time quenching, and austempering.—E. C.

The Low-Temperature Treatment of Steels. E. Kunze. (Stahl und Eisen, 1950, vol. 70, Mar. 16, pp. 227–233). A critical evaluation is made of the literature on the low-temperature treatment of high-speed steels, other tool steels and case-hardening steels. The extent to which cold-treatment is of technical and economic value remains controversial, and the negative results of W. E. Bencroft and W. W. Wight (*see* Journ. I. and S.I., 1948, vol. 159, p. 438) and others appear still to remain undisputed.—R. A. R.

Electron-Diffraction Study of the Cementation of Iron. J. J. Trillat and S. Oketani. (Comptes Rendus, 1950, vol. 230, June 19, pp. 2203–2205). By the application of electron diffraction to extremely thin films of iron produced by volatilization it was possible to follow in detail the mechanism of the gaseous cementation of the iron in the presence of carbon monoxide, and to show the different phases corresponding to different temperatures and different times of cementation. The iron films were produced on fresh cleavage surfaces of rock salt by volatilization of pure iron or mild steel in a vacuum ; the salt was then dissolved away and the iron film collected on a nickel grid.—A. E. C.

Prepared Protective Atmospheres. E. G. de Coriolis. (Iron and Steel Engineer, 1950, vol. 27, Apr., pp. 76–82). The development of prepared atmospheres is reviewed and the principal types of atmosphere used today for processing steel are discussed. The method of preparation, general characteristics, and applications of annealing gases are given. Starting from the original annealing gas analysis : CO_2 5 to 6% ; CO 9 to 10% ; H_2 10 to 12%, CH_4 0·5% ; H_2O dewpoint + 40° F. ; N_2 remainder, the author examines the influence of increasing the nitrogen content and describes the use of this gas in the field of special steels. A third gas, commonly designated as HMX gas, is described, which represents the latest developments in controlled atmospheres for the processing of high standard steel-mill products. Other atmospheres are also examined and stress is laid on the fact that, while prepared atmospheres are generally designed for the prevention of surface deterioration during annealing, they can also be used to rectify the detrimental effects of processing.—M. D. J. B.

The Selection of Furnaces in Heat Treatment. I. S. Reid. (Canadian Metals, 1950, vol. 13, Feb., pp. 31–35, 51). After classifying the radiation type of heat-treatment furnace into three kinds, the electric resistor, the muffle, and the radiant tube, the author describes the equipment and treatment for many parts for motor cars and lorries.—R. A. R.

Implications in High Speed Heating for the Steel Industry. F. O. Hess. (Iron and Steel Engineer, 1950, vol. 27, Jan., pp. 63–73). The author discusses the advantages which can be obtained by high-speed heating and supports his arguments by a number of microphotographs showing the disappearance of grain boundaries after high-speed annealing. Photographs and descriptions of high-speed radiant gas heating units are given together with operating speeds and time–temperature curves for heating and quenching. The possibility of obtaining different characteristics for steels prepared under identical conditions is briefly discussed and the feasibility of explaining this by the use of the electronic microscope is considered. Atomic structure and grain size are considered in relation to behaviour of steels. A special test for investigating the influence of heating time on steel plasticity is described.

M. D. J. B.

Successful Operation of a Modern Commercial Heat Treating Plant. G. H. Porter and E. H. Jeffries. (Industrial Heating, 1950, vol. 17, Feb., pp. 316–328). A description is given of the heat-treatment shops of the Geo. H. Porter Steel Treating Co., Cleveland, Ohio, which now has separate departments for treating tool steels, and small and large commercial work.

R. A. R.

Tractor Gears Heat-Treated Automatically. (Machinist, 1950, vol. 94, Apr. 29, pp. 637–640). An automatic high-frequency heat-treatment unit installed at the Ford Motor Co. Ltd., Dagenham, is described. This unit, installed in the flow line for the production of tractor bull gears, is fully automatic after loading and a gear is treated every two minutes. The period of heating and time the gear is in the quenching oil can be controlled by means of the timing mechanism.—R. F. F.

Effect of the Hardenability of a Steel on the Results Obtained in Flame Hardening. H. W. Grönegress. (Stahl und Eisen, 1950, vol. 70, Mar. 2, pp. 192–196). The effect of the hardenability of two steels (No. 1 : C 1%, Mn 2%, V 0·1% ; No. 2 : C 1%, Cr 1·2%) on the results obtained with flame-hardening has been investigated. The hardening behaviour could be conveniently related to Kubasta's critical diameter (the specimen diameter at which a core hardness 95% of the surface hardness was obtained). The conclusions were : (1) The hardening time and surface hardness are independent of the critical diameter ; (2) under equal conditions and dimensions of piece the depth of hardness increases directly with the critical diameter ; (3) a minimum depth of hardening of 2 mm. is always obtained when flame-hardening, independent of

critical diameter and dimensions; and (4) with increasing critical diameter, under the flame-hardening conditions of this investigation, it becomes more difficult to obtain the calculated depth of hardness with increasing diameter of bar, as there is insufficient time for complete temperature equilibrium to be reached.—R. A. R.

Automatic Hard Facing Improves Quality, Cuts Costs. E. C. Hurst. (Machinist, 1950, vol. 94, Apr. 8, pp. 475–477). The use of automatic flame-hardening at the Kokomo plant of Haynes Stellite Co. is described. The advantages of automatic hard-facing over hand torch hard-facing are: (1) Costs are reduced, (2) the product is more uniform and can be made to conform more closely to specified requirements, and (3) less rejections due to pits or voids in the applied facing. The work treated includes cutter knives and cylindrical surfaces.
R. F. F.

FORGING, STAMPING, DRAWING, AND PRESSING

Metallurgical and Technical Control in Drop Forging. H. J. Merchant. (Australian Institute of Metals: Australasian Engineer, 1950, Feb. 7, pp. 65–75). The metallurgist's work in the supervision of drop forging is discussed under the following headings: Raw Materials—Acceptance, Inspection, and Testing; Metallurgical Acceptance Tests; Aluminium Alloys for Forging; Copper Alloys for Forging; Forging Manufacture—Technical Control; Finished Forging—Inspection and Testing.—R. A. R.

Drop Forging. (Anglo-American Council on Productivity, Productivity Team Report, Apr., 1950). This is the report of a team representing the British drop-forging industry which visited 13 drop-forging plants in the U.S.A. in 1949 under the auspices of the Anglo-American Council on Productivity. Considerable space is devoted to the furnaces as well as to forging operations. Safety and welfare are also commented on.
R. A. R.

Transverse Ductility Variations in Large Steel Forgings. E. A. Loria. (Transactions of the American Society for Metals, 1950, vol. 42, pp. 486–498). Studies have been made of the effect of ingot size and reduction by forging on the ductility of specimens cut transversely from forgings from 36-in. and 48-in. ingots. The greatest number of low values occurred in forged sections from the bottom of the ingots. To develop the relationship between forging reduction and the ratio of longitudinal to transverse reductions of area in tensile tests, average values obtained are presented. The data demonstrate that the maximum beneficial effect of forging on reduction of area of longitudinal specimens is reached when the forging ratio is 2 : 1; between 2 : 1 and 4 : 1 practically no further increase in reduction of area occurs. The transverse reduction of area of forged material from two 72-in. ingots containing different amounts of segregated sulphides was studied. The values obtained were, on the average, as high for specimens having well distributed segregates as for specimens relatively free from short stringers.
R. A. R.

Forged Steel Rolls—A Review of Their Application and Manufacture. A. H. Waine. (Newport and District Metallurgical Society and the Sheffield Metallurgical Association: Journal of The Iron and Steel Institute, 1950, vol. 165, July, pp. 277–286). The general application of forged steel rolls, their potentialities, and advantages over chilled iron rolls are discussed. The three main groups of forged steel rolls, carbon steel, semi-hard alloy steel, and hardened steel, are dealt with separately, their methods of manufacture and particular applications in the hot and cold rolling industries being described. Hardened steel work rolls are considered in detail, and particular reference is made to the value of hardenability tests for their heat-treatment.

The use, calibration, and maintenance of the scleroscope for determining the surface hardness of rolls is considered, and attention is drawn to the recent advances in technique which have enabled rolls of 100–103 'C' Shore body hardness to be manufactured for high-class finishing purposes.

The high precision craftsmanship required for the grinding and finishing of the hardened rolls is reviewed. Some unusual examples of failures in service are described.

Electro-Hydraulic Production of Cranks. (Canadian Metals, 1950, vol. 13, Feb., pp. 38–39). A machine for making crankshafts for Massey Harris agricultural machinery from straight lengths of cold-rolled steel bar 1 $\frac{1}{16}$ in. in dia. is described. The machine combines electrical resistance heating with bending in hydraulic clamps to form the throws. It takes about 1 min. to bring the bar up to 2000° F. with a current of 50,000 amp. at 14 V. All operations are automatic and a crank is made every 4$\frac{1}{2}$ min.—R. A. R.

New Method of Making Knife Blades. (Metalurgia y Electricidad, 1950, vol. 14, Apr., p. 64). [In Spanish]. This brief note refers to the invention of F. R. Francis of Sheffield for the manufacture of knife blades from sheet instead of bar. A combination of electric heating and hydraulic pressure is used to produce one blade every 15 sec. No details of the process are given.—R. S.

Investigations of the Origin of Die-Forging Defects. H. Rauhaus. (Stahl und Eisen, 1950, vol. 70, Mar. 30, pp. 253–264). The defects in die forgings can nearly always be assigned to one of the following groups: (1) Error in the dimensions of the blank; (2) the blank is not placed in the centre of the die; (3) the angle to which the blank has been bent does not match the angle in the die cavity; (4) uneven distribution of flash; and (5) too high gas pressure in the die cavity. Several examples of the defects which arise in each case are described and methods of preventing them are dealt with.—R. A. R.

Power Presses and Metal Forming Practice. (Machinist, 1950, vol. 94, Apr. 15, pp. 575–578). The developments of power presses during the last 50 years are briefly discussed.
R. F. F.

The Production of Circular Tube-Like Hollow Bodies. H. L. Hilbert. (Die Technik, 1950, vol. 5, Feb., pp. 69–70). A die-pressing and welding method for the rapid production of cylindrical or tapering circular tubes from flat metal sheets is described. Instructions are given for calculating the die and mandrel sizes and radii for curling the sheet to tube shape in three stages.—R. A. R.

Report of the Pressed Metal Productivity Team. (Anglo-American Council on Productivity, Productivity Team Report, 1950). The team of ten members of the British pressed metal industry which visited 16 plants in the U.S.A. to study their methods presents its report. The main features of American press plants contributing to high productivity are: (*a*) The productivity consciousness of those engaged in industry at all levels; (*b*) efficient utilization of labour; (*c*) mechanical and semi-mechanical handling equipment; (*d*) line-production methods and flexibility of plant layouts; and (*e*) high-volume production to meet the large consumer market.—R. A. R.

Deeper Draws at Less Cost. (Steel, 1950, vol. 126, Feb. 27, pp. 66–68, 70). A description is given of the 'Marform' process of pressing. This system combines the forming ability of a steel die with the use of rubber for the normal female portion of the tool. A reduction in area of 57% and a cup depth of 1$\frac{1}{2}$ times the radius is normal for aluminium alloys: sheet metal parts can be made to a tolerance of 0·0005 in.—A. M. F.

New Deep Drawing Technique. D. Reebel. (Steel, 1950, vol. 126, Feb. 13, pp. 82–83, 108). This paper describes the single-stroke drawing of a 38$\frac{1}{2}$ in. dia. steel blank, 0·105 in. thick, into a half section of a propane gas tank 14$\frac{3}{4}$ in. in dia. and 24 in. deep. Success of the operation performed in 18 sec. is largely due to the special dies which include a hollow punch.—A. M. F.

The Production of High Carbon Steel Wire. C. W. Garrett. (American Institute of Mining and Metallurgical Engineers, Institute of Metals Division, Symposium Series vol. 3, 1949, pp. 6–15). Cleaning, patenting, and wire-drawing practices are briefly described. Pickling is done in 7–9% sulphuric acid at 120–140° F. Patenting may be carried out by passing the wire through one lead bath (at 950–1000° F.), or two lead baths (at 1550–1650° and 950–1050° F. respectively), or by electric resistance heating followed by quenching in molten lead, and final quenching in water in each case. High-speed drawing is now carried out with tungsten carbide dies, the wire being lubricated with soluble metallic soap with a fatty acid base. Data on the physical properties of cold-drawn 0·73% carbon steel are presented.—R. A. R.

New Calculator for Wire Drafting. N. Piret. (Wire Industry, 1950, vol. 17, July, pp. 587–588). A description is given of a new disc-shaped calculator, based on the logarithm

of the reduction in area, which has been designed for the rapid calculation of die sets.—R. A. R.

ROLLING-MILL PRACTICE

The Building of Rolling Mills. M. A. Fiennes. (Journal of the Institution of Production Engineers, 1950, vol. 29, Feb., pp. 68–88). The plant, organization, and problems involved in the building of rolling-mill machinery are described with numerous illustrations of work in progress at the Davy and United Engineering Co., Ltd., Sheffield. The problem of reducing idle machine time is one of the most important; some of the workpieces are heavier than the machines which work on them, and, to enable machines to be brought to the job, a large and massive cast-iron floor plate covering an area 130 ft. × 60 ft. is being laid down. This will be capable of taking more than one workpiece and several boring machines and facing spindles. A borer may be working on one piece while the next piece, to which the borer is moved later, is being set up.—R. A. R.

Development Trends in the Rolling of Steel. S. Geleji. (Bányászati és Kohászati Lapok, 1950, vol. 5, Feb.–Mar., pp. 203–215). [In Hungarian]. This is a general paper on modern rolling-mill practice. Increase of the efficiency of rolling mills, mechanization, and quality improvement are discussed. It is emphasized that the present tendency is to replace individual, separately controlled stands by roll trains which are centrally controlled. Particular attention is paid to methods applicable for production on a relatively small scale. In the discussion A. Tetmayer pointed out that it would be advantageous to apply Sendzimir cold-rolling stands for producing thin sheets and transformer sheets; information on these stands is given.—E. G.

The Present and Future of Power Electronics in the Steel Industry. L. A. Umansky. (American Iron and Steel Industry, May, 1950, Preprint). The principles of mercury-arc rectifiers are explained with diagrams of a typical circuit and a section of a mercury pool rectifier tank. Some installations in American steelworks are briefly described. At the present time sealed rectifiers are available in sizes up to 500 kW. at 250 V., and 1000 kW. at 600 V. Larger rectifiers with pumps have been in use at some works, *e.g.*, the Kaiser Steel Company has just put in service two 5000-kW. units for its 86-in. hot strip mill.—R. A. R.

Use of Electronics for Main and Auxiliary Steel Mill Drives. W. R. Harris. (American Iron and Steel Institute, May, 1950, Preprint). The electronic installations described in this paper are: (1) A 2500-kW. 600-V. ignitron rectifier supplying power for several motors driving a semi-continuous merchant bar mill; (2) a fast-response speed regulator designed to minimize the transient speed changes that occur when the metal enters the rolls of individually driven rod mill stands; (3) electronic speed control for flying shear drive; (4) electrostatic air cleaner for use with the ventilation of large motor rooms; (5) a plating current regulator to ensure correct tin coating on steel strip at all line speeds; (6) induction heating to reflow tin; (7) photo-electric scanner to control the flow of tin; and (8) photo-electric loop regulators in strip mills. R. A. R.

Improvements in Heavy Reversing Mill Trains by Rectifier Drive. H. Bauer. (Stahl und Eisen, 1950, vol. 70, Feb. 2, pp. 90–96). The principles of rectifier control for rolling-mill motors are explained and technical details of circuits are given for heavy reversing-mill motors with a torque of 350 mt. driving cogging mills with rolls up to 1150 mm. in dia. R. A. R.

New Research into Roll Pressures and Power Consumption in the Hot Rolling of Steel Strip. (Ball Bearing Journal, 1950, No. 1, pp. 3–19). Investigations have been carried out on the effect of speed factors on the roll pressure, and on the dependence of the power consumption and increase in length, when hot rolling steel strip, on the relationship between the thickness of the strip before the pass, the roll diameter, and the reduction. The experiments were conducted with a four-high mill with work and back-up rolls 205 and 425 mm. in dia. respectively. An increase in roll pressure is obtained at increased speeds and the absolute amount of this increase rises at first with the relative linear reduction up to 20–25% reduction, after which it decreases and finally disappears at higher reductions with the result that the curves for the three work-roll speeds of 150, 470, and 950 r.p.m. converge. The position of the area where the curves converge seems to depend on both the composition of the steel and the temperature.—R. A. R.

Contribution to the Study of the Forces during Rolling. V. Stremsdoefer. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Apr., pp. 237–259). The author is of opinion that the formulæ put forward by other investigators to calculate the pressure and the couple applied in rolling are not entirely satisfactory, and he presents his own mathematical study of the problem; he compares the results produced by his own formulæ with those derived by Ekelund's equations and with experimental values obtained in rolling blooms, thin sheet, and foil.—A. E. C.

Relations between Roll-Force, Torque and the Applied Tensions in Strip-Rolling. R. Hill. (Institution of Mechanical Engineers, Apr., 1950, Advance Copy, pp. 3–8). Expressions are derived for the roll-force P, and torque G, in strip-rolling under tension, as functions of the pressure distribution on the rolls and of the radius of the deformed arc of contact. By consideration of various artificial distributions of pressure, the ratio G/P is shown to depend only slightly on the precise shape of the friction hill, and a linear relation is deduced between G/P and T/P, where T is the difference between the front and back tensions.—R. A. R.

A Theoretical Investigation of Roll Flattening. D. R. Bland. (Institution of Mechanical Engineers, 1950, Apr., Advance Copy, pp. 9–12). A method of finding the distortion of the roll surface when subject to a known pressure distribution is described. This method is then combined with a plastic-flow theory of rolling to determine the shape of the arc-of-contact and the pressure distribution over it when neither of these are known beforehand. It is concluded that Hitchcock's solution (A.S.M.E. Report of Special Research Committee on Roll Neck Bearings, 1935) is within the limits of error of the more fundamental solution and remains the most suitable method, for practical purposes, of allowing for roll flattening.—R. A. R.

Power Supply and Electrical Features of Sparrows Point 68-in. Hot Strip Mill. F. O. Schnure. (Iron and Steel Engineer, 1950, vol. 27, Apr., pp. 83–87). Details are given of the new Pennwood power station erected at Sparrows Point, comprising two 25-cycle, 30,000/33,000-kW. turbo-generator units. Modern high-speed protective relaying is installed. Details are also given of the five motors operating the breakdown stands and of the ventilating and cooling systems used. The control room, mill tables, flying shears, and oilers are described. The hourly tonnages and the power required per ton of hot-rolled strip are also given.—M. D. J. B.

Main Mill Drives for Sparrows Point 68-in. Hot Strip Mill. H. W. Bartling. (Iron and Steel Engineer, 1950, vol. 27, Apr., pp. 88–92). The author describes the reasons which led to the choice of a 5-stand roughing train in preference to a conventional broadside mill. Details are given of the five synchronous units of the roughing stands and also of the direct current finishing stand motors. A separate auxiliary exciter set as well as two 750-kW. rectifiers operating from a single inert-gas-filled transformer are described. The electrical controls of both the roughing and finishing stand units are also described in detail.—M. D. J. B.

The Life of Chilled Cast-Iron Rolls. A. Bichler. (Hutnické Listy, 1950, vol. 5, Mar., pp. 89–93). [In Czech]. The author makes a statistical comparison between the chilled cast-iron rolls scrapped in Czechoslovakia between 1935 and 1937, which had a high service life, and those produced in 1948. The factors affecting the roll life, *e.g.*, the chemical composition, the casting temperature and speed, the working conditions, ageing time and the ratio of the ageing plus idle time to the working time, are analysed. The graphs show: (1) The service life of the rolls produced from 1931 to 1948; (2) the carbon, manganese, silicon, and phosphorus contents of rolls of short and long service life; (3) casting temperatures and casting speeds of 223 rolls scrapped in the years 1945–1948; (4) the percentage of rolls broken in 1948 owing to excessive operating temperatures and of those broken owing to excessive working pressures; and (5) the influence of the ageing time, idle time, and the ageing plus idle time on the service life. The author stresses the importance of long ageing and idle times for obtaining rolls of high durability.—E. G.

Bevelling and Rounding-Off in Roll Pass Design. A. E. Lendl. (Iron and Steel Institute, 1950, Translation Series, No. 406). This is an English translation of a paper which appeared in Stahl und Eisen, 1949, vol. 69, Apr. 28, pp. 306–308. *See* Journ. I. and S.I., 1950, vol. 164, Jan., p. 109.

Roll-Neck Bearings—Aspects of Their Development. W. P. Snedden. (Iron and Coal Trades Review, 1950, vol. 160, Mar. 17, pp. 603–611). Progress in the design of roller bearings over the past 25 years is reviewed. The various types of bearing that have been used are considered and include the latest type of balanced proportion bearing.

J. C. R.

An Evaluation of Oil Purifiers for Steel Mill Service. J. I. Clower. (Iron and Steel Engineer, 1950, vol. 27, Apr., pp. 58–66). The problem of rolling-mill lubrication is discussed in relation to the high rolling speeds reached in recent years. Stress is laid on the necessity for well-designed equipment, the choice of correct lubricants, and, most important, the need for giving lubricants proper care while in service. The author describes the formation of sludge and some of the complex phenomena which occur in the deterioration of oils. Gravity, centrifugal, and pressure type oil purifiers are described and numerous drawings are given illustrating both the principles and the commercial versions of these purifiers.

M. D. J. B.

Roll Design for Small Shapes. W. H. Mohler. (Iron and Steel Engineer, 1950, vol. 27, Feb., pp. 63–68). Some of the problems encountered in the design of rolls for small shapes are discussed. With the aid of numerous illustrations, the author describes the passes that are required to produce a number of intricate sections. The difficulties which the roll designer encounters are discussed and the methods of overcoming them given.—M. D. J. B.

Rolling Mills for 5 to 10 mm. Rods. F. del Moral. (Metalurgia y Electricidad, 1950, vol. 14, Mar., pp. 67–69). [In Spanish]. The problem of roll-pass design for producing rods with cross-sections up to 50 sq. mm. is discussed.—R. S.

Looping and Repeating on Merchant Mills. W. J. Barry. (Iron and Steel Engineer, 1949, vol. 26, Apr., pp. 110–115: Association of Iron and Steel Engineers Yearly Proceedings, 1949, pp. 240–244). The author describes how hand looping was replaced by completely mechanized repeating at the 12-stand mill of the Bethlehem Steel Co. which rolls bars for bolts and nuts. The increased tonnage with the mechanical repeaters rapidly wore out the chilled-iron entry guides; these were replaced by nickel–chromium steel guides which have about 50 times the life of the former type. Photo-electric cells controlling solenoids have also been installed to move guides and control rotary shears, and brass bearings have been replaced by fibre bearings. These changes have raised production from 15 to 27 tons/hr.—R. A. R.

French Steel Sheets. (Iron and Steel, 1950, vol. 23, Feb., pp. 55–57). **Reconstruction of French Sheet Mill.** (Sheet Metal Industries, 1950, vol. 27, Feb., pp. 109–110, 116). A short illustrated account is given of the reconstructed sheet mill of the Forges de Leval-Aulnoye, France. The plant consists of a bar furnace with an output of 12 tons/hr., a 3-high mill, three 2-high mills, two pack furnaces, an annealing furnace, a doubler, and ancillary equipment such as pack-return conveyors, discharge conveyors, and automatic roll polishers.—R. A. R.

The Rolling of Stainless Steel. J. A. De Fries. (Iron and Steel Engineer, 1950, vol. 27, Jan., pp. 129–132). The author describes some of the difficulties encountered in the rolling of stainless steels. Broadly, these may be divided into two groups, the chromium and the chromium–nickel alloy steels. The properties of the two types determine to a large extent the handling technique from the ingot onwards. Because of the high content of alloying elements the steels are fairly hard at normal rolling temperatures. The robust mills for working stainless steels are briefly described; rolling speeds, temperatures, and ingot sizes are given. Stress is laid on the importance of good quality control. Modern trends, new alloys and their behaviour are also discussed.—M. D. J. B.

The Production of Steel Plates in Scotland. J. A. Kilby. (Journal of The Iron and Steel Institute, 1950, vol. 166, Sept., pp. 29–70). This paper deals, from historical and technical viewpoints, with the manufacture of steel plates in Scotland, with particular reference to engineering aspects of the subject. The more important developments in works in this area are considered, and descriptions of plants where steel plates have been made are included; statistical information is also given. Present-day production methods will form the subject of a later paper.

LUBRICANTS AND LUBRICATION

The Pour Point of Lubricating Oils and the Fundamentals of the Deparaffining Processes. E. Terres. (Archiv für das Eisenhüttenwesen, 1950, vol. 21, Mar.–Apr., pp. 89–95). The demand for lubricating oils with a low pour point has confronted the makers of oils with problems the difficulties of which are not understood by the users. The physical–chemical fundamentals of the processes involved are explained.

R. A. R.

Training of Steel Plant Lubrication Personnel. W. M. Schuck. (Iron and Steel Engineer, 1950, vol. 27, Mar., pp. 78–82). The author discusses lubrication in steelworks and explains how, with modern machinery, the problem has grown both in importance and in complexity. Men responsible for lubrication should be made fully conscious of the importance of their work and given special practical and theoretical training in the use, choice, and application of lubricants. A scheme for training personnel from apprentices, mechanics, and foremen to engineers is described; in this the author stresses the benefits which will accrue from making all grades of maintenance men familiar with the principles of lubrication as well as giving the lower-grade men a sense of responsibility and pride in their work. Plant lubrication surveys, periodic testing of oil circuits, consumption reports, and the study of new practices are advocated as being the best means of standardizing lubricants and equipment, effecting economies, and introducing improvements.—M. D. J. B.

The Importance of Surface Oxide Films in the Friction and Lubrication of Metals. E. D. Tingle. (Transactions of the Faraday Society, 1950, vol. 46, Feb., pp. 93–102). Most metals when 'cleaned' in air are covered with a surface film of oxide. This fact has not always been sufficiently considered when interpreting what happens when metals, dry or lubricated, slide over one another at slow speeds and under heavy loads. This paper describes an investigation of the effect of oxide films on the friction of metal surfaces sliding under these conditions. The first part deals with clean unlubricated surfaces, the second with surfaces which are lubricated with a thin 'boundary' film of a polar, long-chain, carbon compound.

Metal Attack by Long-Chain Fatty Acids in Oily Friction. J. Pomey and F. Loury. (Métaux et Corrosion, 1949, vol. 24, May, pp. 135–144). The important work on oiliness presented by Bastow, Bowden, and the English school at the Sixth Conference of Applied Mechanics in Paris in 1946 led to the publication of hitherto unpublished data from research on oiliness carried out in the Renault laboratories between 1934 and 1936.

Oiliness can be defined as the aptitude for giving a low coefficient of friction at low velocity and under high pressure, under conditions where viscous hydrodynamic lubrication is not possible. It is shown that oiliness necessitates chemical reaction of a long-chain fatty acid on metallic surfaces with the formation *in situ* of a monomolecular, adherent, rigid layer of soap. The influence of the following factors is reviewed: (1) The length of chain; (2) concentration; (3) time required for the exhaustion of the acid by chemical reaction; (4) time in relation to the velocity of the reaction and the solubility of the soap formed, and (5) the moisture adsorbed which, by the hydrolysis of soap, regenerates the fatty acid. Stearic acid is more suitable than oleic acid in which the double bond leads to a monomolecular film of half thickness and half molecular density as well as to more soluble soaps.

The metals are classified in order of their reactivity with fatty acids in an organic medium. The more reactive, such as cadmium, are those which give the lowest coefficients of friction.

It is shown that the ether salts and the glycerides constituting the natural fat bodies, are, by themselves, devoid of oiliness, but that their hydrolysis liberates the necessary fatty acid. The same applies to the metallic salts capable of hydrolysis or the organic base salts dissociable by heat.

Oily lubrication necessitates a corrosion of the metal which ceases when the surface is covered by a continuous layer of

soap, but which continues as soon as friction causes an instantaneous 'tearing' of the soap film formed. Oily friction thus causes a certain amount of wear.—R. S.

Cold Deformation of Steels. J. Bary. (Métallurgie, 1950, vol. 82, June, pp. 481–482). 'Drawing Bonderite' is a special phosphate lubricant which enables cold deformation to be applied with a minimum amount of work-hardening. The coating is in the form of fine phosphate crystals. The advantages of Bonderite and its applications in the drawing of tubes, sections, and wire, and in deep drawing, strip rolling, and the manufacture of extruded hollow bodies are mentioned.—R. S.

How to Control Friction and Heat in Cold Drawing. E. L. H. Bastian. (Iron Age, 1950, vol. 165, May 11, pp. 77–79, 82). Recommendations are made for the lubricants to be used when cold drawing carbon and stainless steel, copper, brass, aluminium, and aluminium alloys.—A. M. F.

Lubrication of Steel Cables. F. Costa, jun. (Boletim da Associação Brasileira de Metais, 1948, vol. 4, July, pp. 358–373). [In Portuguese]. The author aims to explain in a practical manner the methods used in lubricating steel cables. A useful summary of recommendations is given under the headings: Type of equipment; service conditions; type of lubricant; and method of application.—R. S.

WELDING AND FLAME-CUTTING

Developments in Welding Equipment and Technique. A. J. Hipperson. (Machinist, 1950, vol. 94, Apr. 15, pp. 559–562). The author gives a historical account of the developments of welding equipment and technique.—R. F. F.

Steel Weldments Modify Crane Fabrication, Lower Production Costs. D. Reebel. (Steel, 1950, vol. 126, Jan. 30, pp. 50–52). The Alliance Structural Co. and Alliance Machine Co. have found that the use of weldments is simplified by the use of a 500-ton press brake, and they are producing lighter, better-looking crane components with attendant production savings. However, for some specific parts, a combination of both weldments and castings produces the best product at the most reasonable cost.—A. M. F.

How to Work Clad Materials. W. M. Stocker, jun. (Machinist, 1950, vol. 94, May 13, pp. 711–726). The author discusses the fabricating methods and the heat-treatment of clad metals with special emphasis on the welding techniques to be used.—R. F. F.

Welding High-Pressure Tubes. M. Jirásek and R. Krňák. (Svařování, 1950, vol. 10, Apr., pp. 47–51). [In Czech]. Various standard methods of welding high-pressure tubes, based on inserting metallic or ceramic rings in the joint inside the tube, are briefly discussed, and a new method is described. This method consists of reinforcing the outside weld by one made inside the tube through two small apertures 8×12 to 15 mm. positioned at 180°. The application of this method is described for tubes in a horizontal position, rotatable and fixed, and also for vertical tubes. The new method is a good one for both factory and field use. X-ray analysis of the welds did not reveal any faults and the dimensional tolerances of the tubes to be joined can be larger than for other welding methods. A description is also given of a jig fitted with wheels and a hydraulically operated sleeve; it is placed inside the end of one tube, and the end of the other tube is placed over the projecting part of the jig. The sleeve is hydraulically pressed on to the joint of the tubes to be welded, thus reducing errors in alignment and manufacturing tolerances. Internal stresses in the joint can be eliminated by pressing the sleeve of the jig on to the hot seam and stressing it above the tensile strength value. This jig is used in the U.S.S.R. mainly for building long, straight, inter-city pipelines.—E. G.

Better Welds Expected from New Electric Tube Welding Process. J. B. Borgadt. (Steel, 1950, vol. 126, Feb. 13, pp. 99–100, 102, 104). An air-operated intermittent machine employing surface contact electrodes to convey current across the seam cleft of the tube is used in this process. Successful combination of mechanical and electrical devices produces a good tube weld with fine grain structure. The same machine has been used for both mild steel and stainless, but for the latter more care is essential.—A. M. F.

Welding of Two Different Steels with Austenitic Electrodes. J. Weinzettl. (Svařování, 1950, vol. 10, Apr., pp. 38–46). [In Czech]. The problem of joining two different steels by welding with austenitic electrodes is discussed. The Maurer diagram and equations expressing the effect of the individual alloying elements on the formation of austenite and ferrite the Schaefler equation defining the phase boundaries, and the graphical solution in the case of multi-layer welds are dealt with. These concepts are applied to steels and electrodes of Czech manufacture.—E. G.

How to Make Consistent Spot Welds. J. Heuschkel and H. Bitzer. (Steel, 1950, vol. 126, Feb. 6, pp. 82–86, 110–118) Uniform high-quality welds can be produced only by following a pre-welding control procedure. The authors show the use of statistical methods in determining the suitability of schedules covering the variables of current, time, force, and the electrode size for steels of various thickness, temper, and surface conditions. The tension-shear strength value is taken as a figure for control, and graphs illustrate the effects of these variables.—A. M. F.

Resistance Welding in Czechoslovakia. K. Jarský. (Svařování, 1950, vol. 10, Mar., pp. 22–26). [In Czech]. General information is given on the manufacture and application of resistance-welding machines in Czechoslovakia. Illustrations showing Czech welding machines are included.—E. G.

Recommended Practices for Resistance Welding. (American Welding Society, 1950). This 60-page booklet is a modification and expansion of the Standard issued in tentative form in 1946. It includes welding schedules for the spot and seam welding of mild and medium-carbon steels, low-alloy steels, stainless steels, nickel, Monel, Inconel, and magnesium alloys, as well as for projection and flash welding. Specifications for methods of testing resistance welds are included.—R. A. R.

Application of Resistance Welding in Portugal to Reinforced Concrete Bars. V. Machado de Carvalho. (Maquinas e Metais, 1950, Feb., pp. 8–11). [In Portuguese]. Difficulties associated with the usual methods of joining long bars are stated. The processes of resistance butt welding and of resistance flash welding are briefly described, and the advantages of the latter are outlined. Examples of the application of this method in Portugal are quoted.—R. S.

Weldability of High-Alloy Steel. W. P. van den Blink. (Lastechniek, 1950, vol. 16, Feb., pp. 17–21). [In Dutch].

Steel Plant Maintenance. S. D. Baumer. (Iron and Steel Engineer, 1950, vol. 27, Feb., pp. 74–80). The importance of maintenance in the iron and steel industry is stressed and the need for specialized industries to help provide the high standard of maintenance required is recognized. In this field the outstanding tools are flame-cutting and oxy-acetylene and electric arc welding. Examples are given of emergency and routine repairs to blast-furnace plant, rolling-mill housing, and open-hearth furnace doors. Examples are also given of the latest types of cutting and welding equipment and of the new uses for them which are constantly being brought into the iron and steel industry.—M. D. J. B.

Repair of a 3000-Ton Hydraulic Press. E. N. Lynd. (New Zealand Engineering, 1950, vol. 5, Feb. 15, pp. 159–160). A description is given of the repair by electric welding of a cracked cast-steel cylinder, 36 in. inside and 48 in. outside dia., for a 3000-ton press. A gas-fired furnace was built up round the cylinder which was slowly preheated to 300° F. and the mass of metal was kept at this temperature throughout the welding operation which took seven days.—R. A. R.

Influence of Carbide-Forming Elements on Underbead Cracking of Low Alloy Steel. R. S. Stewart and S. F. Urban. (Transactions of the American Society for Metals, 1950, vol. 42, pp. 653–665). The addition of powerful carbide-forming elements to two hardenable steels (a chromium–molybdenum and a nickel–molybdenum steel) markedly reduces the tendency to crack under the bead during arc welding. The effectiveness of the elements in decreasing order is titanium, zirconium, niobium, and vanadium. Further improvement is obtained by spheroidizing the steels before normalizing.

R. A. R.

Faults in Arc Welds in Mild and Low Alloy Steels. (Welding Research, 1950, vol. 4, Feb., pp. 3r–15r). In this memorandum typical faults which can occur in arc welds in mild and low-alloy structural steel construction are defined and illustrated; an outline is given of the reasons for their occurrence, and of the ways in which they may be avoided or corrected.

R. A. R.

Controlling Welding Distortion. C. G. Bainbridge. (Canadian Metals, 1950, vol. 13, Feb., pp. 41–44). The movement of metal during expansion and contraction and the effects of

restraint in different directions are explained. These explanations are applied to the case of fillet and butt welds, and recommendations are made with a view to minimizing distortion. These include : (1) Keep welds as small as possible ; (2) complete the weld in as few passes as possible ; (3) weld as fast as possible ; (4) select electrode for highest deposition efficiency and produce a flat weld face ; (5) break down large weldments into sub-assemblies ; (6) balance the welds ; (7) distribute weld metal and heat as uniformly as possible to the joint ; (8) weld outwards from a central point ; (9) weld downhand whenever possible ; and (10) restrict the hot zone by keeping metal adjacent to joint as cool as possible.

Selection of Welding Machines for Lime-Coated Electrodes and Influence of the Machine on the Penetration Depth of the Weld. S. Josifek. (Svařování, 1950, vol. 10, Feb., pp. 2–9). [In Czech]. Experiments have been carried out to determine the suitability of various types of welding generator for arc welding with deep penetration using lime-coated electrodes. The results obtained are given in tables, graphs, oscillograms, and photographs of sections of welds showing the depth of penetration.—E. G.

Welding Electrodes in the U.S.S.R. (Svařování, 1950, vol. 10, Mar., pp. 35–36). [In Czech]. This paper contains general information on the development and manufacture of electrodes in the U.S.S.R.—E. G.

Improved Design of a Holder for Welding Electrodes. (Svařování, 1950, vol. 10, Feb., pp. 17–18). [In Czech]. A new design of a holder of welding electrodes is described. It has no springs and the pressure on the electrode is applied by a threaded part, the movement of which is controlled by rotating the front and back parts of the handle in opposite directions.—E. G.

New Electrode Holder. (Svařování, 1950, vol. 10, Mar., pp. 32–33). [In Czech]. An electrode holder made of mild steel, recently developed at the Skoda Works, is described. The holder is of a very simple design and is very easily dismantled by pressing a spring. The electrode can be held at any angle.—E. G.

Fatigue Strength of Various Types of Butt Welds Connecting Steel Plates. W. M. Wilson, W. H. Munse, and I. S. Snyder. (Illinois University, 1950, Engineering Experiment Station Bulletin Series No. 384). Using 0·20–0·25% carbon steel plate $\frac{3}{4}$ and $\frac{1}{2}$ in. thick, tensile fatigue tests were carried out on plain and on transverse and longitudinally welded specimens. One purpose was to determine whether welding costs could be reduced without sacrifice of safety by making 'partial-penetration welds' in which the butt joints in $\frac{3}{4}$-in. plate were welded to depths of only $\frac{1}{2}$ in. and $\frac{3}{16}$ in. on each side. With longitudinal welds of this kind, not stress-relieved, the values of stress to cause fracture after 100,000 and 2,000,000 cycles were very nearly the same as for similar unwelded plate with the mill-scale on. For $\frac{3}{4}$-in. plate, with $\frac{1}{4}$-in. partial-penetration transverse welds, the stress to fracture after 100,000 cycles was 43% of that for full-penetration welded specimens.—R. A. R.

An Investigation of the Stress Distribution in a Welded Plate Girder for the Margam Plant. S. Mackey and D. Brotton. (Structural Engineer, 1950, vol. 28, Feb., pp. 28–42). The tests described were carried out on a quarter-scale model, 20 ft. long, of one of the 12-ft. deep crane runway girders for the Margam steelplant in South Wales. Analysis of the results showed that the provision of web stiffeners welded to the flange plates contributed substantially to the torsional resistance of the girder.—R. A. R.

The Properties of Weldments at Low Temperatures. R. D. Stout. (A.S.T.M. Symposium on Effects of Low Temperatures on the Properties of Materials, Mar. 19, 1946 : Special Technical Publication No. 78, 1950, pp. 51–62). Specimens of ship-plate steel 12 × 3 in. with a weld down the centre and two shallow-transverse notches were bent slowly at temperatures ranging from + 150° to − 100° F. and the angles of bend at maximum load were noted. The results for a number of steels and welding conditions are shown by plotting the angle against the testing temperature. The composition of the steel is the most important factor affecting the properties of the weldment. Post-heating to 1150° F. is particularly effective in restoring ductility to the plate after welding.—R. A. R.

Welding Problems in the Puertollano Power Station. First Industrial Application of Gamma Rays in Spain. (Dyna, 1950, vol. 25, Feb., pp. 76–77). [In Spanish]. The national undertaking of Calvo Sotelo is building a 50,000-kW. power station in the industrial centre of Puertollano. Details of the boiler installations by the Foster Wheeler Corp. are described and the difficulties of double welding the collecting mains are discussed. Checking was effected by radiographic means. Due to the size (12$\frac{1}{4}$ in. dia. × 1 in. thick) and position of the boiler tubes, it was not possible to use the portable industrial X-ray equipment and recourse was had to gamma rays. Iridium 192 (of 220 millicuries with a half life of 70 days) was imported by air from England.—R. S.

CLEANING AND PICKLING

Gas-Pickling of Steel. J. Pearson, W. Bullough, and T. C. Canning. (Journal of The Iron and Steel Institute, 1950, vol. 165, June, pp. 185–190). The treatment of steel strip in atmospheres containing gaseous hydrochloric acid has been practised in the U.S.A. for preparing the material for subsequent hot-galvanizing. Laboratory investigations have confirmed that galvanized coatings adhere more tightly to steel prepared in this way than to steel pickled in aqueous sulphuric acid. The attack on steel by gaseous hydrogen chloride differs from that by aqueous acids. The process is, however, suitable only for steel which can be heated to temperatures of about 750° C. without loss of required properties. Steel which must be finished in a cold-worked condition or with special heat-treatment cannot therefore be submitted to gas-pickling. Neither is the process suitable for the removal of thick scale ; the rapid attack of the gaseous HCl on any bare steel revealed by non-uniform removal of scale, leads to heavy metal losses and marked unevenness of surface.

Acid Resisting Plastic Pickling Plant. (Wire Industry, 1950, vol. 17, Feb., p. 145). Some particulars are given of a plastic material called 'Keebush' from which pickling tanks and other acid-resisting equipment can be moulded. It can be safely used at temperatures up to 200° F. It withstands thermal shock without danger of cracking, has a low thermal conductivity and a high electrical resistance.

Acid-Resisting Ceramic Coatings in Descaling Plant. L. Koegel. (Métaux et Corrosion, 1950, vol. 25, May, pp. 135–142). The various types of construction for descaling tanks and the conditions which they have to withstand are described. Reinforced concrete tanks coated with acid-resisting ceramics, when correctly designed, should give complete satisfaction. Details of coating compositions are not given, but the author gives some useful practical hints on design and operation of ceramic-coated pickling plant.

Conditions in plant for the neutralizing of spent pickle liquors and recovery of the acid are reviewed, and installations for storing acid, discharge pipes, and absorption towers are described.—R. S.

Continuous Strip Pickling. D. Brownlie. (Canadian Metals, 1950, vol. 13, Mar., pp. 14, 53). The author outlines modern practices using a four-tank continuous cascade system. Acid (strength 23–26% by volume) enters No. 4 tank only and drains from No. 1 tank (strength decreased to 9–11%). Details of tanks, practices of rinsing, drying, and re-coiling are discussed in brief. Acid consumption ranges between 35–70 lb./ton of strip, with pickling speeds up to 400 ft./min.
E. C.

Acid Dips in Cleaning Cycles. I—Acid Dips for Low Carbon Steel. I. C. Hepfer. (Proceedings of the American Electroplaters' Society, June 28–July 1, 1949, pp. 127–132). The 'pros and cons' of the use of hydrochloric and sulphuric acids for removing scale and cleaning steel before plating are briefly discussed. In general, a hydrochloric acid dip will give the best results for the greatest variety of conditions.

Acid Dips in Cleaning Cycles. II—Acid Dips for High Carbon Steel. R. M. Wick. (Proceedings of the American Electroplaters' Society, June 28–July 1, 1949, pp. 132–137). In general, sulphuric acid is not recommended for pickling high-carbon steel before plating, hydrochloric acid is preferred. For degreasing, anodic alkaline cleaning is recommended, as cathodic cleaning introduces some risk of hydrogen embrittlement.—R. A. R.

When to Use Electrolytic Polishing. C. E. Naylor. (Australian Department of Supply, Defence Research Laboratories : Plating Notes, 1950, vol. 2, June, pp. 91–95). The limitations of electropolishing as a production process and its use in conjunction with mechanical polishing are described. Suitable

metals in approximate order of ease of electropolishing are: Austenitic stainless steels, other stainless steels, pure aluminium, electroplated nickel and silver, nickel-silver, copper, cartridge brass, and plain carbon steels. The greatest possibilities for the process probably lie in the processing of large numbers of small intricately shaped articles which are difficult and costly to polish by mechanical means.—R. A. R.

Application of Electrolytic Polishing to the Study of Chromized Steels. P. Galmiche. (Métaux et Corrosion, 1950, vol. 25, Mar., pp. 65–66). The brightness of chromized parts can be improved by electrolytic polishing. Best results are obtained by using the Jacquet cold acetic-acid/perchloric-acid bath with the perchloric acid concentration increased to 20–30%. Voltage is thus reduced to 10–12 for a current density of 20–40 amp./sq. dm., thus permitting the treatment of parts with large surfaces without any marked heating of the bath.

Analysis of the chromium content in the skin presents certain difficulties. The chemical analysis of turnings machined from a fixed depth gives only an approximate value of the chromium content, especially for thinner layers. Neither is measurement of microhardness variations advisable in view of the very slight differences in hardness of the various iron–chromium alloys (excepting compositions corresponding to the region of the sigma phase). X-ray examination is also unsuitable.

Spectrographic analysis permits a precise study over a wide range of analyses, but demands perfectly clean surfaces corresponding to fixed depths. Electrolytic polishing, by a simple measurement of the loss in weight related to the surface of the specimen, gives an exact determination of thickness removed. Plain or cylindrical specimens are used for the anode, and a cylindrical strip of stainless steel for the cathode.—R. S.

Industrial Electrolytic Polishing. Present Developments and Future Prospects. R. Mondon. (Metallurgia Italiana, 1950, vol. 42, Mar., pp. 95–102, 104). The author discusses the present-day developments of electrolytic polishing and its industrial applications. He also discusses the changes of properties of metallic materials due to electrolytic polishing. R. F. F.

The Use of Glycerine in Electropolishing. M. A. Lesser. (Metal Finishing, 1950, vol. 48, Mar., pp. 75–77). The electropolishing processes for stainless steel using solutions of phosphoric acid or sulphuric acid with glycerine and water are cited from the literature to which there are 17 references.

Selection and Application of Cleaning Room Equipment. S. Krzeszewski. (American Foundryman, 1950, vol. 17, Apr., pp. 96–101). Comparisons are made in the advantages and costs of cleaning castings by different methods such as tumbling, blasting with sand and metal shot, and high-pressure water jets. Metal shot are now more popular than sand for cleaning owing to the longer life.—R. A. R.

Laboratory Investigations on Metal Cleaning. S. Spring. (Metal Finishing, 1950, vol. 48, Mar., pp. 67–72, 74). An investigation of the removal of mineral oil and machining lubricants from steel panels by an alkaline silicate cleaner containing a surface-active agent has been made at room temperature using dilute solutions and photographing the various stages of formation of droplets from the oil film. Mineral oil is more easily removed from non-pickled than from pickled cold-rolled steel; on the other hand, previous pickling assists the removal of a sulphurized lard oil containing free fatty acid. Pure lard oil, low in free fatty acid, behaves similarly to mineral in the cleaning solution. The efficiency of oil removal decreases rapidly with increasing viscosity of the oil.—R. A. R.

De-Enamelling. B. B. Kent. (Institute of Vitreous Enamellers: Foundry Trade Journal, 1950, vol. 88, Feb. 2, pp. 123–126). Methods of carrying out de-enamelling are described, particular accounts being given of the caustic soda solution process which is suitable for flat articles where large quantities can be packed into the de-enamelling tank and the temperature of 140° F. is not likely to cause distortion or buckling, and of the process of immersion in molten caustic used for more bulky articles.—J. C. R.

PROTECTIVE COATINGS

Electrolytic Deposits without the Use of Electric Current. A Revolutionary Innovation in the Field of Metallic Coatings. (Tecnica e Industria, 1950, vol. 28, Feb., pp. 169–170). [In Spanish]. The article refers to a U.S. Bureau of Standards method based on chemical reduction of the metals in hot hypophosphite solutions. The deposits are sufficiently adherent and approximate to 95% purity. The structure of the coatings is at once lamellar and columnar, and somewhat resembles deposits of specular nickel. One great advantage of this coating technique is that the need for generator, rheostats, etc., is obviated. Parts for plating are wrapped with wire and placed in the bath. Agitation is necessary. Details of compositions of solutions for bright and semi-bright nickel, cobalt, and cobalt–nickel coatings are given.—R. S.

Automatic Electroplating. L. Walter. (Overseas Engineer, 1950, vol. 24, Aug., pp. 6–8). The instrumentation and control used for continuous electroplating plants are discussed and constructional details are given of the temperature measuring and controlling systems.—R. A. R.

Some Notes on the Electroplating of Powder Metallurgy Parts. H. H. Hausner. (Metal Finishing, 1950, vol. 48, Mar., pp. 73–74). The surface pores in powder metallurgy parts greatly increase the surface area, and a higher current density is required for electroplating them. The following method has been developed for plating porous iron parts: (1) Heat the compact in air to 400° F.; (2) quench in a solution of Dow-Corning No. 200 silicone with 96% carbon tetrachloride or perchlorethylene; (3) dry and bake at 400° F. for 30 min.; (4) pickle in type of solution to suit base metal; (5) wash in cold water; (6) use usual plating procedure; (7) wash in cold water; and (8) dry and inspect. Other methods from the literature and patents are cited.—R. A. R.

The Measurement of Coating Thickness by Electrical Means. H. C. den Daas. (Metalen, 1950, vol. 4, Feb., pp. 110–114). [In Dutch]. Non-destructive methods of measuring the thickness of coatings on metals are reviewed; these include electromagnetic, inductive, capacitance, and acoustic methods. R. A. R.

Taper Sectioning. E. Rabinowicz. (Metal Industry, 1950, vol. 76, Feb. 3, pp. 83–86). Surface finish may be studied by first protecting the surface with an electrodeposited coating, then sectioning the specimen at a small angle to the surface, *e.g.*, 6°, and finally preparing micrographs. The method is described and some results obtained in the study of surface friction are shown.—R. A. R.

Anodes. E. R. Thews. (Metalloberfläche, 1950, vol. 2, Feb., pp. B25–B28). Factors affecting the solubility of anodes in electroplating baths are discussed with special reference to the physical condition of cast anodes. Slowly cooled cast brass anodes have a fairly dense fine-grained structure at the surface and a coarse-grained interior so that, when the surface layers have dissolved away, decomposition of the interior proceeds rapidly until a grid-like structure is left and loose crystals lie below it on the bottom of the bath. The structure and the life of cast anodes can be greatly improved by hammering them. Hammered nickel anodes form practically no scum. Anode scum may divide itself into three parts, one falling to the bottom of the bath, one in suspension which may settle on the cathode, and one remaining on the anode which, if not removed, may render it passive.—R. A. R.

An Electro-Deposited Surface Roughness Standard. P. M. Aitchison. (Australian Journal of Applied Science, 1950, vol. 1, Mar., pp. 71–74). An electrodeposited surface roughness standard and its use are described. The standard consists of a lapped steel block on which are deposited thin strips of chromium of specified width, spacing, and height. This provides a known surface for use in the calibration of stylus-type instruments for measuring surface finish.—R. A. R.

Outstanding Problems of Porous Structure in Electrodeposits. N. Thon. (Proceedings of the American Electroplaters' Society, June 28–July 1, 1949, pp. 241–249). Progress in research on the causes and prevention of porosity in electrodeposits is reported. Gas-permeability tests on electrodeposited foils of nickel, copper, silver, and iron revealed a fine porosity varying with the nature of the metal and the conditions of deposition. Work is proceeding on determining the rate of permeation through the same foil of gases of different molecular weight. At equal thicknesses silver foils are considerably more porous than nickel, and iron foils are even more porous; copper comes between nickel and silver. Nickel from pure sulphate is more permeable than nickel from pure chloride. Experiments indicate that deposits on

a polished surface are from two to five times more porous than when produced on an etched crystalline surface; this applies to nickel and iron on copper, and for silver on iron. Tests indicate that a bright smooth nickel foil is more permeable than the usual 'dullish' nickel of equal thickness. Electron diffraction studies have shown that, with nickel deposits, gradually increasing brightness, stress, and permeability are accompanied by gradually disappearing preferred orientation.—R. A. R.

The Present Status of Plating-Room Waste Disposal. C. F. Gurnham and B. F. Dodge. (Proceedings of the American Electroplaters' Society, June 28–July 1, 1949, pp. 251–263). Illustrated descriptions are given of some large and small American plants for the treatment of acid and cyanide wastes from plating installations.—R. A. R.

Modern Developments in Metal Finishing. E. A. Ollard. (British Industrial Finishing, 1950, vol. 2, Apr., pp. 633–639). Electroplating equipment and control are discussed. The relative merits of motor generators and rectifiers are pointed out. A rectifying unit with a little transformer which transforms the current and alters the voltage before it goes to the main transformer is briefly described. A chromium-plating tank, heated by a water jacket, is usually lined with a lead–antimony alloy. A nickel tank is generally lined with hard or semi-hard rubber. Linings of polythene sheets $\frac{1}{2}$ in. thick are recommended rather than sprayed polythene. Tank heating, and pumps and filters for plating solutions are also briefly reviewed.—R. A. R.

Mechanism of the Transportation of Chromium and Other Elements in Gaseous Cementation. P. Galmiche. (Comptes Rendus, 1950, vol. 230, Mar. 20, pp. 1181–1183). In the cementation process described volatile chromium fluoride is formed; this reacts with the steel objects to be treated (which are not in contact with the cementing agent) and with hydrogen (of which a little is introduced into the cementation box) thus:

$$CrF_2 + Fe = FeF_2 + Cr,$$
$$FeF_2 + H_2 = Fe + 2HF.$$

The hydrofluoric acid then reacts with chromium or ferrochromium in the box, and regenerates the supply of CrF_2. In cast irons and carburized steels a thin continuous film rich in chromium carbide forms. By combining this method with another similar one using volatile chlorides, articles can be cemented with other elements such as aluminium, zirconium or silicon in addition to chromium.—A. E. C.

Some Factors that Influence the Operating Characteristics of Chromium Plating Baths. R. O. Hull and J. B. Winters. (Proceedings of the American Electroplaters' Society, June 28–July 1, 1949, pp. 93–101). The optimum plating conditions for plating chromium over buffed nickel coatings deposited in a Watts bath, and over bright nickel coatings have been investigated. The chromium bath that shows the least passivation is the one containing 33 oz./gal. (U.S.) chromic acid and has a sulphate ratio of 100 : 1. Raising the bath temperature by only 10° from 110° to 120° F., tends to cause passivation in the chromium bath. The cold-water rinse between the nickel and the chromium baths should not exceed 2 min. and the time in the chromium bath before the current is applied must not exceed 15 sec.—R. A. R.

The Analysis of Chrome Plating Solutions. L. Silverman. (Metal Finishing, 1950, vol. 48, Feb., pp. 46–54). Procedures for the determination of the following components and impurities in chromium-plating solutions are given: (1) Chromic acid and tervalent chromium; (2) sulphuric acid; (3) iron; (4) copper; (5) zinc; (6) nickel; (7) aluminium and iron; (8) tin in tin–lead anodes; (9) antimony in antimonial lead anodes; and (10) chromium trioxide and sulphuric acid in anhydrous chromic acid.

An explanation of the catalytic action of the sulphate ion and the necessity for its presence in the chromium bath is offered.—R. A. R.

Scratch Hardness and Abrasion Hardness of Electrodeposited Chromium. J. M. Hosdowich. (Proceedings of the American Electroplaters' Society, June 28–July 1, 1949, pp. 103–126). Indentation hardness, scratch hardness, and abrasion tests have been made on chromium-plated steel (by T. H. Webersinn under the author's direction) to study the effect of different plating conditions. In general, deposits of the same appearance have the same scratch hardness regardless of the current densities and temperatures at which they were produced. As long as the chromium deposit comes out of the plating solution bright or slightly frosty in appearance, it has a hardness equivalent to about 1000 Brinell; if the bright plating appears to be 'soft' it is because the basis metal is too soft and the chromium deposit too thin.—R. A. R.

Electrodeposition of Nickel at High Current Density. W. A. Wesley, W. W. Sellers, and E. J. Roehl. (Proceedings of the American Electroplaters' Society, June 28–July 1, 1949, pp. 79–92). The theoretical maximum current density at which nickel deposition can be the principal process taking place at the cathode, *i.e.*, the electrochemical 'limiting current density' (l.c.d.) is calculated. Nickel chloride solutions have fundamental advantages over nickel sulphate solutions for high-current-density work. The l.c.d. for sound nickel deposits increases approximately linearly with the rate of flow of electrolyte over the cathode surface. With a flow rate of 750 ft./min. sound nickel deposits were obtained from the chloride nickel bath at cathode current densities as high as 4260 amp./sq. ft. With a measured flow rate of 10 ft./min. the l.c.d. was 400 and 300 amp./sq. ft. for chloride and Watts baths, respectively. Even at this flow rate it should be possible to double present average nickel-plating rates. The nickel coatings prepared at very high current densities were less ductile and slightly harder than those made from the same solution at normal rates.—R. A. R.

Contribution to the Study of Electrolytic Galvanizing. J. Ginguené. (Métaux et Corrosion, 1950, vol. 25, May, pp. 126–134; June, pp. 156–163). Suggested compositions for acid and alkaline baths and the influence of the constituents are described. The analytical and the drop methods for measuring thickness of the coating are reviewed. Many of the faults in galvanizing baths are related to the anodes. The variation of bath characteristics in relation to density of current with pure zinc anodes is studied. The results are compared with data obtained using zinc alloy anodes.

The behaviour of pure zinc and zinc alloy anodes in alkaline baths and the characteristics of the anodic film in relation to current density are explained.

Electrolytic alkaline galvanizing baths used at the present time all contain zinc cyanide $Zn(CN)_2$ and sodium zincate Na_2ZnO_2. The author studies the possibility of using baths prepared only from oxides of zinc and sodium. Two baths were prepared as follows: (1) Zinc oxide 50 g./l., and soda 80 g./l.; (2) zinc oxide 50 g./l., soda 80 g./l., and sodium cyanide 40 g./l.

The addition of sodium cyanide permits high current densities. With the zincate bath the deposit becomes powdery above 0·8 amp./sq. dm.—R. S.

Use of Aluminium in Hot-Dip Galvanizing. M. L. Hughes. (Journal of The Iron and Steel Institute, 1950, vol. 166, Sept., pp. 77–84). The first section of this report consists of a review of the somewhat contradictory views expressed in the literature on the subject of aluminium additions in hot-dip galvanizing. The advantages claimed for this practice include improved lustre, diminished rate of bath oxidation, increased corrosion resistance of the coating and, with heavier additions, the elimination of the usual iron–zinc alloy layers. The last is the most important since it has a marked effect on the bending properties. Certain disadvantages also arise when aluminium is used, notably fluxing difficulties. The statements made in the literature regarding these advantages and disadvantages are discussed, and the theories put forward to explain the action of aluminium in producing alloy-free coatings are reviewed.

The second section describes experiments to determine the minimum amount of aluminium needed to eliminate alloy layers or to reduce these to such an extent that adequate bending properties are obtained. Four steels have been tested under various dipping conditions. In most of the published work immersion times were much longer than those used in sheet galvanizing and in many cases the temperatures were very high. The present work has therefore been limited to shorter immersion times and to the normal range of operating temperatures.

Current theories on the mechanism by which alloy-free coatings are produced from baths containing aluminium are shown to be incorrect, and it has been found that, under suitable conditions, an alloying process different from the normal one may occur.

Revamped Production Facilities Boost Pipe Galvanizing 30%. D. Reebel. (Steel, 1950, vol. 126, Feb. 20, pp. 85–86). The Wheatland Tube Co. claim a 30% increase in pickling and galvanizing production of pipe and a substantial saving in zinc from a redesigned plant. The primary factor is a set of four permanent magnet pipe rolls set in tandem used for the drag out from the galvanizing pot.—A. M. F.

Zinc Dust Collected by New System Installed at Pipe Galvanizing Plant. G. E. Brock and D. B. Shindler. (Steel, 1950, vol. 126, Jan. 16, p. 63). An account is given of the method of removing excess spelter and reclaiming excess zinc and zinc oxide from the inside of dip-galvanized pipes, by a blast of high-pressure steam. A properly designed dust-collecting system is essential to eliminate the fume and fire hazards.—A. M. F.

Pot Life in Gas-Fired Galvanizing Settings. A. Higgs. (Institution of Gas Engineers, Symposium of Short Papers, 1950, Communication No. 370, pp. 25–29). Three methods of heating zinc baths for galvanizing are described. In one, low-pressure gas burners (with natural-draught injectors) are fitted at close centres under the refractory-lined top plates of the setting. These are fitted with fish-tail burner nozzles to provide a wide flame front ; the flames are produced downwards and parallel with the pot sides. Withdrawing of the hot waste gases by an eductor facilitates their further use for heating drying ovens. In the second, the pot walls are heated by molten salt in the surrounding jacket, the salt being heated by immersion burners. In the third, lead is the medium of heat transmission, the lead being heated by immersion tubes.—R. A. R.

Packaging Tin Plate. D. H. Dellinger. (American Iron and Steel Institute, May, 1950, Preprint). Methods and specifications for the packaging of tinplate are discussed and some methods illustrated.—R. A. R.

Uses of Rubber to Protect Metals against Corrosion. C. A. Garcia Ferrer. (Maquinas e Metais, 1950, Feb., pp. 29–30). [In Spanish]. The author discusses the rôle of vulcanized rubber linings to protect metals against corrosion and abrasion and to protect the contents of containers against contamination. The Vulcalock process of Goodrich and the patented Triflex material consisting of a layer of hard rubber sandwiched between two layers of soft resilient rubber (the whole being vulcanized) are mentioned. A brief description of the process of applying rubber sheets to metals is given to enable certain aspects of design to be more clearly understood.—R. S.

Phosphate Treatments for Iron and Steel Surfaces. H. A. Holden. (Electroplating, 1950, vol. 3, Feb., pp. 213–214 ; Mar., pp. 244, 245, 248). The phosphatizing processes for iron and steel are reviewed, with explanations of the chemical reactions and descriptions of the equipment.—R. A. R.

Some Investigations on Black Oxide Finishes. H. Silman and B. E. Love. (Journal of the Electrodepositors' Technical Society, 1950, vol. 25, pp. 65–76). Investigations have been carried out on the corrosion-resisting properties and thicknesses of black oxide coatings produced from a solution of sodium hydroxide, sodium nitrate, and sodium dichromate. Methods of measuring film thickness are described ; they indicate that it is of the order of 0·00005–0·0001 in. The protective value of the coating is higher on steels containing nickel and chromium, even in amounts as low as 1%, than it is on plain carbon steels, when tested by immersion in fuels and water. In tests in the humidity chamber the protective value of the oxide film was negligible. X-ray diffraction examination showed that the coating consisted of Fe_3O_4 on all steels, but with 3% or more of chromium, traces of Cr_2O_3 were also formed.—R. A. R.

Avoiding Failures in the Metal-Spraying Process. H. Reiniger. (Metalloberfläche, 1950, vol. 2, Feb., pp. B22–B24). Examples of unsatisfactory repairs by the metallizing process are described and their causes are explained. These are taken from a paper by J. E. Wakefield entitled " Metallizing Failures to Avoid " (*see* Journ. I. and S.I., 1949, vol. 162, June, p. 237).—R. A.

Flame Spraying of Metals and Plastics in Engineering and Shipbuilding. F. A. Rivett. (Transactions of the Institution of Engineers and Shipbuilders in Scotland, 1948–49, vol. 92, pp. 331–354). After a brief description of the metal-spraying pistol which can spray metals and alloys with a melting point below 1600° C., and many fusible non-metallic substances, the author describes some applications, including several cases of zinc spraying to prevent marine corrosion. To protect steel from heat scaling, good results are obtained by 'aluminizing,' *i.e.*, spraying with aluminium followed by heat-treatment at about 850° C. to diffuse the aluminium into the steel.

Sprayed plastics form a completely fused coating. Of these, polythene has very good electrical insulating properties and is unaffected by acids and alkalis at temperatures up to 80° C. Sprayed Thiokol is a tough, flexible, and abrasion-resisting coating which can also be sprayed ; it has been used to protect condenser doors against corrosion by hot sea water.

The Hot Spraying of Lacquers. A. E. Lain. (Oil and Colour Chemists Association : British Industrial Finishing, 1950, vol. 2, May, pp. 708–716). The composition of lacquers and the conditions under which they can be hot sprayed are discussed. They are more costly in use and require the installation of special equipment. The hot-spraying operation is more laborious than normal spraying. The temperature of the lacquer falls very quickly when it meets the atomizing air ; a thermometer placed in the spray fan at various distances from the nozzle, with the lacquer temperature in the circuit at 76° C., gave the following readings : 46°, 38·5°, and 31° C. at distances of ½, 3, and 6 in. from the nozzle respectively ; the shop temperature was 26·5° C.—R. A. R.

PROPERTIES AND TESTS

The Strength of Steel. A. C. Vivian. (Mechanical World, 1950, vol. 127, Feb. 3, pp. 115–118). Long-time tests were carried out on ¼-in. dia. test pieces by applying weights to a platform attached to the lower end while the upper end was attached to the ceiling beam. Loads increasing from 1540 to 2530 lb. in nine stages were applied and the extensions on 5 in. after 5 min. and 24 hr. were noted. With the 2530-lb. load (23 tons/sq. in. stress) the extensions were 0·21 and 0·24 in. respectively ; this load was maintained for six weeks with no increase in extension. The load was then increased to 2640 lb. (24 tons/sq. in.). The extension after 5 min. was 0·25 in. and there was no further extension in one week. It is shown that, above the yield point, steel is elastic and plastic at the same time.—R. A. R.

Mechanism of the Flat Portion of Tensile Test Curves for Annealed Steels. C. Boulanger. (Comptes Rendus, 1950, vol. 230, Mar. 13, pp. 1072–1074). The cause of the flat portion in stress–strain curves is discussed. The case of annealed steels is linked up with the general case of cold-worked and aged alloys by invoking a mechanical effect determined by the change of specific volume which accompanies the $\gamma \rightarrow \alpha$ transformation, followed by ageing during cooling.—A. E. C.

Simplification of St. Gállik's Calculation for Converting the Elongation of One Gauge Length to Another Gauge Length. J. Verö. (Bányászati és Kohászati Lapok, 1950, vol. 5, Apr., pp. 279–280). [In Hungarian]. The author has developed two series of curves, which are presented, to enable elongation values obtained on one gauge length to be converted to another gauge length without having to measure the permanent elongation, as was necessary with St. Gállik's method.—R. A. R.

The Tensile Impact Properties of Some Metals and Alloys. D. S. Clark and D. S. Wood. (Transactions of the American Society for Metals, 1950, vol. 42, pp. 65–74). The theory of elastic and plastic strain propagation is reviewed and the results of tensile impact tests in a special machine on ingot iron, several plain carbon steels (carbon from 0·12 to 0·90%), chromium–nickel–molybdenum steels, 19/8 stainless steel, and some non-ferrous metals and alloys are reported. The ultimate strength, elongation, and energy absorption under both static and dynamic conditions are presented graphically for all the materials. The critical velocity for each material is defined and the experimental values for this are compared with the computed values. The ultimate tensile strength of all materials tested was greater under dynamic than under static conditions. The advantages of quenching and tempering and of austempering are presented from the standpoint of tensile impact properties.—R. A. R.

Relation between the Impact Fracture and the Microstructure of Two Low-Alloy Steels with Differing Degrees of Temper Brittleness. P. A. Jacquet. (Comptes Rendus, 1950, vol. 23, Mar. 27, pp. 1284–1286). Specimens of Ni–Cr and

Ni–Cr–Mo steels (composition not stated, but of low alloy content), after oil-quenching from 850° C., were either tempered at 650° C. and water-quenched or tempered at 525° C. and cooled very slowly. Notch-toughness specimens were broken in impact, and sections cut in such a way as to pass through the rounded bottom of the notch were prepared. The mode of fracture under impact could be related to the microstructure. The lowest notch-toughness figures, for tempering in the embrittling range of temperature, corresponded to an almost exclusively intercrystalline fracture in the Ni–Cr steel and to a fracture both inter- and transcrystalline in the Ni–Cr–Mo steel; in both cases the plastic deformation was negligible. The higher notch-toughness values, for specimens treated at the higher temperature and quenched, were associated with an intergranular fracture and considerable deformation, which latter was greater in the molybdenum-bearing steel.—A. E. C.

The Effect of Cold-Work on Steel. J. H. Andrew and H. Lee. (Journal of The Iron and Steel Institute, 1950, vol. 165, June, pp. 145–184; Aug., pp. 369–395). In an earlier paper (*see* Journ. I. and S.I., 1942, No. I, p. 135P) the authors advanced the hypothesis that austenite was formed in steel during cold-working, but this theory has not been generally accepted as proved for normal forms of cold-working. There are indications, however, that with dynamic loading where the deformation is extremely rapid and localized, or in the case of working which involves intense heat due to surface friction, the formation of austenite and martensite does occur. At the same time, the various effects of internal strains upon physical and mechanical properties of steel are not sufficiently realized. It was with this in mind that the present work was undertaken. As a result, the effect of internal strains in ferrite and in cementite upon some of the properties of steel can be differentiated, and it appears that austenite formation in steel is restricted to special forms of cold-working involving either dynamic loading or intense surface friction.

The experiments described were carried out by a number of independent workers, and the paper is therefore divided into several sections.

In Section I, P. L. Chang, B. Fang, and R. Guenot report on the effect of the work-hardening properties of steel.

Hardness, dilatation, density, and thermo-magnetic measurements have been carried out on cold-drawn specimens of a series of plain carbon and certain alloy steels. The difference in the work-hardening properties between high-carbon steels and low-carbon iron is marked. Unlike low-carbon iron, high-carbon steels show a rapid increase in hardness on cold-drawing towards high reductions and, at the early stages of cold-working, the shape of the work-hardening curve is shown to vary with the initial treatment given to the specimens. The results also confirm those of earlier workers, that with cold-worked high-carbon steels there is a marked increase in hardness on tempering up to 300° C.; such a secondary hardening is not evident in cold-worked iron.

Several changes have been observed from dilatation measurements in the longitudinal direction on cold-drawn steel wires, the most marked being an expansion between 150° and 450° C. This change is mainly directional, because the increase in length is accompanied by a contraction in diameter. The change is more pronounced if the carbon content is higher and, with a given steel, when the initial structure is pearlitic rather than sorbitic.

The density of steel decreases on cold-working. With cold-drawn specimens, the maximum decrease is of the order of 0·2–0·3%. On subsequent tempering, the recovery of density takes place mainly between 400° and 700° C. With ingot iron, however, the decrease in density on cold-working and the extent of recovery on subsequent tempering appear to vary with the amount of inclusions present.

Thermo-magnetic experiments have been carried out on cold-worked steels. With a 0·7% carbon steel, cold-drawn beyond about 50% reduction, the cementite Curie point is markedly affected. At 90% or higher reductions, the thermo-magnetic curve is perfectly smooth, showing no discontinuity corresponding to the normal cementite Curie point. The magnetic saturation of the steel at room temperature, however, is apparently unchanged after cold-working. The absence of the normal cementite Curie point has also been observed with tempered martensite.

X-ray examination on a cold-drawn high-carbon steel shows that the intensity of cementite lines is appreciably weakened when the drawing reductions exceed 50%. Micrographic observations confirm that cold-worked steels are prone to graphitization on sub-critical annealing.

In Section II, P. L. Chang and R. Guenot report on the effect of cold-work upon the electrical resistivity in steel.

Electrical resistivity measurements have been extensively carried out on cold-drawn wires, both at room temperature and during or after subsequent heating, and the experimental methods are described in detail. On cold-drawing, the resistivity increases in the case of low-carbon steels or iron, but it decreases with high-carbon steels, as measured in the longitudinal direction of the wires. This decrease is greater if the carbon content of the steel is higher, and for a given steel the change of resistivity on cold-drawing is dependent upon the initial structure of the specimen.

On tempering, the resistivity of a cold-drawn low-carbon iron decreases continuously with increasing tempering temperature up to 550–600° C. With high-carbon steel wires, however, the change of resistivity on tempering is different, especially at low temperatures, where a small increase takes place over the range 150–450° C., with a maximum at about 250–300° C.

The effect of cementite distribution upon the resistivity of steel after cold-drawing has been investigated, and the lowering of resistivity in the longitudinal direction is shown to be less with a sorbitic than with a pearlitic structure. The experimental results are corroborated with the theoretical treatment.

In Section III an account is given by P. E. Brookes of an X-ray study of the internal strains in ferrite in cold-drawn steels. After cold-working, both the macro-strains (as defined by a change of X-ray ring diameter) and the micro-strains (as shown by X-ray line-broadening) are greater with a high-carbon steel than with a low-carbon iron. In the case of a cold-drawn low-carbon iron the macro-strains across the wire section vary from compressive near the surface to tensile at the centre, as measured in the transverse direction, such strains being due mainly to the presence of body stresses. With a cold-drawn high-carbon steel, the presence of textural stress gives rise to macro-strains such that the ferrite is apparently under uniform compression in the longitudinal direction and under tension in the transverse direction of the wire. The recovery of the macro-strains on heating is consistent with the dilatation results given in Section I.

The effect of high-speed deformation, by a dynamic load impact on steel is reported in Section IV by L. Bourne, whose results confirm those of previous workers, *viz.*, that the deformation is extremely localized, giving rise to the formation of a white band. X-ray examination shows this band to contain austenite and martensite.

The structural changes in steel due to cold-working by compression are considered by D. V. Wilson who, in Section V, gives the results of X-ray examinations on high-carbon and alloy steels. No evidence of the presence of austenite in unfractured test pieces was found, although austenite might have formed on the surface of shear fractures. Evidence was found by X-rays that there were large residual strains in cementite with some tendency towards preferred orientation after severe cold-working.

The study of the effect of cold-work on hydrogen in steel was carried out by U. V. Bhat and H. K. Lloyd, who report on their electrolytic method in Section VI. It is shown that cold-work decreases the rate of hydrogen diffusion and increases the saturation. The correlation of these two properties with changes in hardness and density is discussed. In heat-treated specimens there are indications that the state of division and distribution of the cementite present plays a part in determining the rate of hydrogen diffusion in steel.

In Section VII the results reported in the foregoing Sections are correlated and discussed. It is concluded that the austenite theory advanced in an earlier paper is valid only in special cases involving a sudden generation of intense heat during deformation. In normal processes of cold-working, the austenite theory is untenable and the change of properties is explained by the various effects of internal strains in ferrite and in cementite. In the past, whilst the effect of internal strains in ferrite is to some extent well

known, the effect of such strains in cementite and of those arising from the mutual restraint between ferrite and cementite, upon the bulk properties of steel, has not been sufficiently realized. The increased hydrogen saturation in cold-worked steels has also been correlated with X-ray line-broadening, thus supporting the view suggested in a previous paper that the hydrogen introduced into steel at room temperature is mainly accommodated in occluded form at crystallite boundaries or mosaic disjunctions.—R. A. R.

A New Theory for the Solid State. C. A. Zapffe. (Transactions of the American Society for Metals, 1950, vol. 42, pp. 387–398). A new theory for the physical constitution of matter is presented which, so far as the solid state is concerned, can be summarized as follows: The solid state in general, and the solid state for metals in particular, is a condition of aggregation of subcrystalline units of colloidal dimensions, tentatively termed micelles, originating or existing within the previous liquid or gaseous state, and carrying aspects of their definition and separateness into the solid state as an inherently discontinuous structure on a colloidal scale. All mechanical phenomena, such as plasticity and cleavage, and all physical phenomena, such as optical, electrical, and magnetic properties, then depend upon and/or involve the intermicellar surfaces. Chemical phenomena such as transformations and precipitations, nucleate within or develop with respect to this inherited internal surface.—R. A. R.

Use of the Pendulum for the Study of Elastic Properties of Solids. M. Le Rolland. (Non-Destructive Testing, 1950, vol. 8, Spring Issue, pp. 16–19). The theory of the application of the pendulum for measuring the damping capacity of solids is explained and a two-pendulum instrument for the purpose is described.—R. A. R.

A Review of the Electrochemistry of Stressed Metals. M. T. Simnad. (Journal of the Electrochemical Society, 1950, vol. 97, Feb., pp. 31c–44c). The literature on the electrochemistry of stressed metals is critically reviewed. There are 126 classified references.—R. A. R.

The Part of Octahedral Theory in the Study of the Plasticity of Metals. W. P. Roop. (Journal of the Franklin Institute, 1950, vol. 249, Mar., pp. 223–236). When the algebraic relationships of octahedral theory are used for converting fracture data to terms of octahedral stress, it is found that fracture occurs at a value of octahedral stress or strain that is at least roughly constant. When fracture is associated with a limiting value of octahedral stress, the effect of triaxiality is thus completely accounted for.—R. A. R.

An Evaluation of a Theory for Plastic Flow in Anisotropic Sheet Metals. T. H. Hazlett, A. T. Robinson, and J. E. Dorn. (Transactions of the American Society for Metals, 1950, vol. 42, pp. 1326–1356). A simple theory is proposed for correlating plastic deformation in anisotropic work-hardenable metals under combined stresses. This theory assumes that: (1) The strain increments are linear functions of the stresses; (2) the work-hardening is a function of the plastic strain energy; and (3) the kind and degree of anisotropy does not change materially over the ranges of deformation considered. The merits and deficiencies of the theory are evaluated by comparing the actual stress–strain relationships of sheet metals in tension as a function of orientation with those predicted by the theory. The experimental results reveal that several sheet metals are substantially anisotropic. The theory permits fair correlations with the facts in those cases where the degree of anisotropy does not change materially with deformation.—R. A. R.

The Electrical Resistance Strain Gauge. K. Fink. (Max-Planck-Institut für Eisenforschung: Zeitschrift des Vereines deutscher Ingenieure, 1950, vol. 92, Feb. 1, pp. 89–94). The theory, construction, and applications of electrical strain gauges are described and discussed.—R. A. R.

Elongation and Stress Measurements with Thin Resistance Wires. (Strain Gauges). K. Fink. (Mitteilungen aus dem Max-Planck-Institut für Eisenforschung, Report No. 509: Archiv für das Eisenhüttenwesen, 1950, vol. 21, Mar.–Apr., pp. 129–135). The determination of the electrical-resistance/elongation relationship of wires and the construction of strain gauges are described and their application for measuring strain under static and dynamic loads is discussed. An example of each type of application is given by a study of roll pressure, and the construction of force–time curves in a cold-upsetting operation.—R. A. R.

A Dynamic Calibration of Resistance Strain Gauges. K. Fink. (Mitteilungen aus dem Max-Planck-Institut für Eisenforschung, Report No. 510: Archiv für das Eisenhüttenwesen, 1950, vol. 21, Mar.–Apr., pp. 137–142). The pressure wave induced in a cylindrical steel specimen by an impact has been studied photographically with the aid of strain gauges, an amplifier, and a cathode-ray oscillograph. Satisfactory agreement was obtained between the experimentally determined and the calculated wave form. This shows that the resistance strain-gauge technique is suitable for measuring dynamic strains.—R. A. R.

Some Experimental Techniques in Stress Analysis. W. M. Murray. (Year-Book of the American Iron and Steel Institute, 1950, pp. 383–397). Brief descriptions of three methods of stress analysis—photoelasticity, stresscoat, and wire resistance strain gauges—are given.—R. A. R.

Gear-Tooth Stresses at High Speed. W. A. Tuplin. (Institution of Mechanical Engineers, Mar., 1950, Advance Copy). The paper records some reflections on the stresses induced in gear teeth by errors in pitch. Errors of pitch and profile in gear teeth may cause actual stresses to be higher than nominal stresses by an amount that increases with speed in any particular installation, up to a limit that would not be exceeded even at infinite speed. The nominal permissible stress should therefore take account of probable errors in the teeth.—R. A. R.

Discussions of a Century Ago Concerning the Nature of Fatigue, and Review of Some of the Subsequent Researches Concerning the Mechanism of Fatigue. R. E. Peterson. (A.S.T.M. Bulletin, 1950, Feb., pp. 50–56). A description is given of a meeting of the Institution of Mechanical Engineers at Birmingham in 1849, when the nature of fatigue was discussed. This is followed by a review of some of the subsequent researches concerning the mechanics of fatigue which includes metallographic studies, work with single crystals, and aggregates of a few crystals leading up to application of the electron microscope and research at elevated temperatures. There are 43 references.—R. A. R.

Electromagnetic Predetermination of the Probable Fatigue Limit. A. Langevin, E. Paul, and M. Reimbert. (Comptes Rendus, 1950, vol. 230, Mar. 20, pp. 1138–1140). The fatigue limit (or endurance) of a steel can be estimated by the variation of the magnetic permeability curve of the specimen as a function of the tensile stress applied, the variation being determined by the greatest stress previously applied to the specimen.—A. E. C.

The Application of Surface Pressure when Gripping Specimens for Fatigue Tests. G. Denkhaus. (Metalloberfläche, 1950, vol. 4, Feb., p. A17). In the push-pull fatigue testing of round specimens, fracture sometimes occurs at the fillet between the gripped ends and the gauge length. The pressure-rolling of this fillet is recommended and a device for doing this is described. The specimen is revolved in a lathe and a roller 40 mm. in dia. with a rounded face (4 mm. radius) is pressed by a spring (load 60 kg.) against the fillet. There must be a gradual transition zone in which the pressure decreases from 60 kg. to zero. This procedure has no effect on the fatigue properties of the gauge length.—R. A. R.

Machine for Testing Rails in Bending Fatigue. L. B. Banks. (Engineering, 1950, vol. 169, May 26, pp. 585–587). A machine for fatigue testing 15-ft. lengths of 95 lb./yard bullhead rails is described and some results obtained are given. The machine consists of an oscillator or out-of-balance mass attached to the rail, a motor for driving this through a pair of flexible couplings, and a structure for supporting the rail and the motor. The fatigue strength of a batch of new rails of 51·5 tons/sq. in. tensile strength lay between $\pm$ 10·3 and $\pm$ 11·2 tons/sq. in.—R. A. R.

Developments in Hardness Testing. P. Grodzinski. (Machinist, 1950, vol. 94, Mar. 25, pp. 397–401). Two new instruments for hardness testing for harder materials are described. The first is a static indentation hardness tester using a diamond edge indenter with two cones, the other is a micro-abrasion tester which employs a small high-speed grinding wheel on a relatively light load. Methods of use and comparison with other types of tester are discussed.—R. F. F.

Cast Iron from the Point of View of the Purchaser. W. P. Smith. (Institute of British Foundrymen: Foundry Trade Journal, 1950, vol. 88, Feb. 9, pp. 139–146). Some methods of testing grey-iron castings to determine if they will meet

specified requirements, are discussed. As non-destructive tests, the applicability of the Brinell and Rockwell hardness tests are considered. The difficulties encountered in obtaining representative data by destructive testing, even when separately cast test bars are used, are outlined.—J. C. R.

Ageing of Iron and Steel. J. D. Fast. (Société Française de Métallurgie : Iron and Coal Trades Review, 1950, vol. 160, Apr. 14, pp. 837–844). The parts played by oxygen, nitrogen, and carbon in the ageing of unalloyed iron and of manganese-bearing iron have been investigated. Determinations of Vickers hardness show that carbon and nitrogen cause significant quench-ageing in iron that is otherwise pure, whilst the quench-ageing of oxygen-containing iron is very slight. The addition of 0·50% of manganese has no effect on the action of carbon, but practically suppresses the quench-ageing of nitrogen-bearing iron. This effect of manganese was confirmed by measurements of damping. Less than 0·001% of nitrogen suffices to cause maximum strain-ageing. Strain-ageing due to carbon only appears at a noticeable speed at elevated temperatures such as 100° C.—R. A. R.

Age-Hardening of Austenitic Alloys. V. Reniger. (Metallurgie, 1950, vol. 82, May, pp. 379–387). The author describes several ageing tests with iron–wolfram, iron–molybdenum, iron–wolfram–chromium, iron–wolfram–silicon, and iron–wolfram–manganese alloys.

Variations in hardness related to periods of ageing at 600°, 700°, and 800° C. are illustrated. Conclusions are : (*a*) The rate of hardening is more rapid with higher ageing temperatures : (*b*) following solution treatment and hardening, the hardness is proportional to the amount of alloying elements ; (*c*) in the case of binary alloys, the hardness is practically the same for equal contents of alloying elements ; (*d*) maximum hardness obtained is proportional to the content of alloying elements ; (*e*) maximum hardness is practically independent of the ageing temperature in the temperature range 550–800° C., except as regards the steels relatively low in alloying elements. In the latter case, the maximum hardness values, below 600° C., are lower than those obtainable at higher temperatures ; (*f*) starting from 650–700° C. ageing temperature, ageing beyond a certain period causes a drop in hardness due to the phenomenon of 'super-ageing' ; and (*g*) this drop in hardness is all the more rapid and accentuated, the higher the ageing temperature and the richer the steel in alloying elements.

In spite of considerable variation in analysis, the temperatures at which precipitation began and finished, were about the same.

Increase in strength due to ageing was marked only if the alloy did not already contain an almost continuous network of carbides. The content of carbide-forming elements such as tantalum, columbium, molybdenum, and wolfram was therefore important.—R. S.

Experimental Research on the Ageing of Metals in Bridges. A. Berio. (Metallurgia Italiana, 1950, vol. 42, May, pp. 175–179). The results of experiments carried out under static and dynamic loading on samples cut from old wrought iron bridges are discussed. Samples include specimens taken from the Trezzo bridge over the Adda and a number of other bridges over the first section of the Villoresi canal. The tests have permitted an accurate assessment of the present state of the metal, enabling the author to make a true estimate of the soundness of the structures.—M. D. J. B.

Creep of Steel under Static Stress at Room Temperature. W. Jäniche and G. Thiel. (Archiv für das Eisenhüttenwesen, 1950, vol. 21, Mar.–Apr., pp. 105–118). Tensile tests were carried out on six carbon steels (carbon up to 0·48%) after various forms of heat-treatment and with and without natural and artificial ageing. Creep was observed at below the the elastic limit when determining the 0·2% proof stress. When there was a definite elastic limit in a long-time test the beginning of flow was observed only after several hours at a stress which, with one steel, was only 78% of the elastic limit. In some cases a creep rate just below that of 10×10^{-4} % hr. in the standard specification was observed between the 25th and 35th hour at loads in the neighbourhood of the 0·2% proof stress. When the elastic limit is much below the 0·2% proof stress, long-time tests are necessary. The type of creep behaviour which a steel will follow can often be ascertained after 24 hr. if the creep curve is plotted on a semilogarithmic scale, so that only with an unknown material would it be necessary to make tests for longer than 100 hr. It is proposed that the creep limit should be the stress at which an elongation of 0·005% is not exceeded in 100 hr., but with materials the creep of which rapidly ceases, the criterion should be the 'time elongation limit,' *i.e.*, the stress at which 0·01% elongation is not exceeded during the creep.

Subsequent contraction and spontaneous contraction on removing the load are caused by the relief of internal elastic stresses, but the effect can be masked by precipitation phenomena.—R. A. R.

Microsclerometric Analysis of the Temper Brittleness of a Steel with Low Contents of Nickel and Chromium. H. Bückle and P. A. Jacquet. (Comptes Rendus, 1950, vol. 230, June 19, pp. 2198–2200). Meyer analysis was carried out on a low-alloy steel containing carbon 0·3%, nickel 3·25%, and chromium 1·65%, by determining the microhardness of specimens quenched and tempered in various ways. Having regard to the microstructures and the X-ray diagrams the authors are led to believe that temper brittleness is the result of a reversible transformation of the carbides leading to a critical dispersion of the latter and a state of stress, a hypothesis which agrees with the known characteristics of the phenomenon.—A. E. C.

Embrittlement when Tempering High-Phosphorus Steels. E. Houdremont and H. Schrader. (Archiv für das Eisenhüttenwesen, 1950, vol. 21, Mar.–Apr., pp. 97–104). The notched-bar toughness of five chromium–nickel–molybdenum steels, eight unalloyed steels, and five chromium–nickel steels, some with low phosphorus and others high in phosphorus, all hardened and tempered, was investigated. Embrittlement was observed in the high-phosphorus steels not only in the temper-brittleness range but also down to room temperature. The small increase in brittleness, irrespective of phosphorus content, observed in all the steels on ageing at room temperature or at 100° C. was due to the precipitation of carbides. In addition, there was a marked embrittlement at high phosphorus contents which occurred at lower tempering temperatures as the phosphorus increased. There seems to be much evidence that temper brittleness and phosphorus embrittlement are the same thing, and that in both cases it is a matter of embrittlement by precipitation during crystalline segregation.—R. A. R.

The Effect of Electric Traction on the Track. F. C. Johansen. (Institution of Electrical Engineers, Convention on Electric Railway Traction, Mar. 20–23, 1950, Advance Copy). The paper surveys the detrimental effects of multiple-unit electric trains on surface track in England. Reference is made to the factors influencing the performance of the track as a whole, and to the specific forms of rail damage, especially periodic side-cutting.—R. A. R.

The Cause of Anisotropy in Permanent Magnet Alloys. K. Hoselitz and M. McCaig. (Proceedings of the Physical Society, Section B, vol. 62, Mar. 1, pp. 163–170). Measurements of magnetostriction have been made on samples of an anisotropic permanent magnet alloy (Alcomax II). From the results it is concluded that the domain magnetization is, in the absence of a field, along that easy crystallographic direction which makes the smallest angle with the axis of anisotropy. This view is supported by measurements of the remanence. The ideal arrangement which obtains after hardening seems to be slightly disturbed during the subsequent tempering operation.—R. A. R.

Developments in Modern Magnet Alloys. A. Torry and A. Edwards. (Nickel Bulletin, 1950, vol. 23, Mar., pp. 42–46). After a brief survey of progress made in permanent magnet alloys since the beginning of the century, special reference is made to the Alcomax series of anisotropic alloys and their properties.—J. C. R.

Magnet Steels and Alloys. J. Apraiz Barreiro. (Acero y Energia, 1950, vol. 7, Mar.–Apr., pp. 8–14, 39). [In Spanish]. After briefly reviewing the development of magnet steels and alloys, the author states the principal properties of these materials. Magnet steels and alloys fall into four groups : Steels of low coercive force (carbon and chromium–tungsten steels) ; cobalt steels ; nickel–aluminium, and nickel–aluminium–cobalt alloys ; and other alloys with good magnetic properties which are also ductile, malleable, and easy to machine. The properties of each group and of some special

magnet alloys are described and their annealing, hardening, tempering, and magnetization are considered.—R. S.

Magnetic Lag Revealed by Means of a Blow. L. Lliboutry. (Comptes Rendus, 1950, vol. 230, May 3, pp. 1586–1587). Instead of a small variation of the magnetic field a light blow can be used to reveal magnetic lag in a steel. The whole of the lag is disclosed, and not only that in the walls at 90°. A. E. C.

Magnetic and Electrical Properties of Nickel and Its Alloys. R. Dume. (Metalurgia y Electricidad, 1950, vol. 14, Apr., pp. 56–57). [In Spanish]. The author summarizes the electrical and magnetic properties of pure nickel, and some ferrous and non-ferrous nickel alloys, and gives a table of remanence and coercive force.—R. S.

Nickel and Its Alloys. (United States Department of Commerce, 1950, National Bureau of Standards Circular 485). This 72-page Circular reviews available information about nickel and its alloys, with particular attention to the physical properties and applications of the metal, and its ferrous and non-ferrous applications. It is a revision of Circular 100 issued in 1924.—R. A. R.

Improvements and New Results Relating to Measurements of the Variation of the Electrical Resistance of Ferromagnetic Substances as a Function of Temperature. G. Mannevy-Tassy. (Comptes Rendus, 1950, vol. 230, Mar. 20, pp. 1150–1152). The results of new measurements of the variation of the electrical resistance of nickel with temperature up to 1297° K. are plotted in a graph. It is shown that the curves for nickel and iron (on reduced co-ordinates) coincide exactly.—A. E. C.

Preparation and Magnetic Properties of Ferrites of Manganese and of Cobalt. C. Guillaud and H. Creveaux. (Comptes Rendus, 1950, vol. 230, Mar. 27, pp. 1256–1258).

Diamagnetism and Intermittent Activation in Iron–Chromium and Iron–Vanadium Alloys. R. Forrer. (Comptes Rendus, 1950, vol. 230, May 3, pp. 1584–1585).

Thermal Variation of the Spontaneous Magnetization of the Ferrites of Nickel, Cobalt, Iron, and Manganese. R. Pauthenet. (Comptes Rendus, 1950, vol. 230, May 22, pp. 1842–1843).

Influence of Annealings on the Remanent Magnetism of Ferromagnetic Substances. J. C. Barbier. (Comptes Rendus, 1950, vol. 230, May 8, pp. 1643–1645). The effect of annealing a magnetized ferromagnetic substance (the author's experiments were made with Alnico) is to cause a diminution of the square root of the remanent magnetism proportional to the amount by which the temperature was raised.—A. E. C.

Relation between the Crystalline Structure and the Magnetic Properties of the Mixed Ferrites of Nickel and Zinc. M. Sage and B. Guillaud. (Comptes Rendus, 1950, vol. 230, May 15, pp. 1751–1753).

Investigation of the Properties of Metals and Alloys by Magnetic Methods. B. Šesták and L. Jeníček. (Hutnické Listy, 1950, vol. 5, Apr., pp. 155–162). [In Czech]. On the basis of their own work and published literary data the authors describe the application of measurements of the ferromagnetic properties of metals and alloys to the investigation of other properties. The influence of the temperature, chemical composition, change of phase, and the structure is discussed and the methods of investigating this are described with special reference to the magnetic balance and induction instruments used for studying the isothermal transformation of austenite, the residual austenite, and the magnetic anisotropy.—E. G.

Inspection and Classification of Metals Made Easy. B. M. Smith. (Iron Age, 1950, vol. 165, Apr. 27, pp. 95–98). Large parts may be inspected non-destructively and mixed lots of metals separated, by using a newly developed test head called the General Electric Metals Comparator. This equipment works on the basis of impedance comparison and may be used for the control of composition, heat-treatment, hardness, case depth, and plating thickness.—A. M. F.

Magnetic Particle Inspection. L. A. Danse. (Non-Destructive Testing, 1950, vol. 8, Spring Issue, pp. 7–12). The introduction and development of magnetic particle inspection for cracks at the Cadilla Division of the General Motors Corp. are described. This has led to the design of the Duovec machine in which the magnetic field is rapidly shifted in direction by combinations of magnetizing currents.—R. A. R.

Current Applications of Magnetic Analysis Inspection. V. L. Spoley. (Non-Destructive Testing, 1950, vol. 8, Spring Issue, pp. 20–23). Developments in apparatus for the magnetic testing of tubes and bar stock are illustrated and discussed. The apparatus compares the magnetic properties of a tube (for example) 2 in. in dia. with a wall thickness of 0·065 in., as it passes through a test coil at a speed of 30 ft./min., with those of a length of tube of known properties in a second coil. Defects of the order of 0·002–0·003 in. are easily detected by this 'Multi Method' equipment.—R. A. R.

Anomalies of Propagation of Ultra-Sonics in Metals in Relation to the Structure. E. de Kerversau, J. Bleton, and P. Bastien. (Société Française de Métallurgie, Oct. 6, 1949: Revue de Métallurgie, Mémoires, 1950, vol. 47, June, pp. 421–444). During ultrasonic testing, anomalies of transmission and of reflection may occur, giving rise to the appearance of a number of parasitic echoes at various depths which are extremely mobile, and the disappearance of the base echo. The authors present a theoretical study of the mechanism of the production of these anomalies and of the phenomena that take place in more complex structures than those previously examined in an earlier paper, namely, eutectoid and hypereutectoid structures in carbon steels, comparative behaviour of a given nickel–chromium–molybdenum steel in the bainitic and in the pearlitic condition, and an overheated structure in a nickel–chromium–molybdenum steel. The damping capacities of pearlitic and bainitic structures in the same steel and the use of the polarizing microscope to reveal α-grains in steel are dealt with in two appendices.—A. E. C.

Sonic Tests Spot Flaws in Heavy Forgings. R. W. Snowden. (Iron Age, 1950, vol. 165, Apr. 13, pp. 77–81: Apr. 27, pp. 88–90). The use made by the Heppenstall Co., Pittsburgh, of supersonic tests for the location and identification of flaws in heavy forgings is described. Major flaws are detected by examination from the ends and along two axial strips 90° apart. The location of smaller defects, such as segregates, porosity, and small holes requires 100% surface examination. In the second part sonic tests on crankshafts, eccentric shafts, drill stems, and collars with a standard searching unit and an angle searching unit are described.—R. A. R.

Ultrasonics in Industry. (British Engineering, 1950, vol. 32, Mar., pp. 1343–1348). The equipment necessary for the production of supersonic waves, and industrial applications already made and those envisaged are briefly described. A new low-frequency magnetostriction generator, made by Mullard Electronic Products, Ltd. is the first of its kind to be produced.—R. A. R.

Influence of the Form of the Graphite on the Damping Capacity of Cast Irons. A. Portevin, R. Cabarat, and L. Guillet. (Comptes Rendus, 1950, vol. 230, Mar. 6, pp. 891–892). The authors' experiments showed that, whereas the formation of nodular graphite in cast iron had no great effect on the damping capacity of the metal, lamellar graphite increased it considerably; the first particles to form were particularly effective. The modulus of elasticity was also much lower for irons containing lamellar graphite than for those in which it was in the spheroidal form.—A. E. C.

10 MEV. X-Ray Technique. D. T. O'Connor, E. L. Criscuolo, and A. L. Pace. (American Society for Testing Materials, Papers on Radiography, June, 1950, Special Technical Publication No. 96, pp. 10–19). With respect to 10-mev. (million electron volt) radiography, data have been presented on beam intensity distribution, lead screen efficiency, absorption of radiation by steel plate, and penetrameter sensitivity. In addition, ionization shield thickness data have been given as a check on the validity of the radiographic results. It is recommended that 0·030-in. front and back lead screens be used for radiography at this energy. The penetrameter sensitivity which may be expected is 2% at 1 in. and 0·5% at 9 in. of steel. No advantage is to be expected from using lead filters at least up to 9 in. of steel. No precautions need be taken against film fogging by back scatter.—R. A. R.

Mobilizing the Van de Graaf Generator for Precision Radiography. E. A. Burrill. (American Society for Testing Materials, Papers on Radiography, June, 1950, Special Technical Publication No. 96, pp. 34–40). In the electrostatic system of high-voltage generation in the Van de Graaf unit, the voltage for the X-ray tube is produced by an electrically isolated high-voltage terminal continuously charged by a rapidly

moving belt running between the terminal and earth in a voltage-distributing column. The compactness of the generator is achieved by surrounding the column and the X-ray tube with a mixture of nitrogen and CO_2 at about 26 atm. To contain this insulating medium the entire generator is contained in a pressure vessel 36 in. dia. by 63 in. high. The complete generator with target shield weighs about 3000 lb. This generator and a flexible mount on the front of a small motor vehicle are shown to form a unit for use in shipyards and engineering shops where it is impossible to bring heavy parts into the X-ray room for examination.

A Universal Exposure Calculator for Radium Radiography and Its Application to Current Radiographic Films and Techniques. N. A. Kahn, E. A. Imbembo, and J. Bland. (American Society for Testing Materials, Papers on Radiography, June, 1950, Special Technical Publication No. 96, pp. 41–59). The authors describe an exposure calculator for radium radiography, designed and constructed to permit its use as a standardized exposure calculator for steel and other materials and with all types of industrial radiographic film, or with radiographic techniques which aim at image density levels higher or lower than the normal net density of 1·00.

An Investigation of Radiography in the Range from 0·5 to 2·5 Million Volts. W. W. Buechner, R. J. van de Graaf, H. Feshbach, E. A. Burrill, A. Sperduto, and L. R. McIntosh. (American Society for Testing Materials, Papers on Radiography, June, 1950, Special Technical Publication No. 96, pp. 75–95). Radiographic investigations and techniques developed since 1941 at the Massachusetts Institute of Technology are reviewed. The conclusions from the research include: (1) The penetrating power and intensity of 2-million-volt radiation permit production radiography of steel up to 8 or 10 in. thick, and quantitative examination of steel up to 14 in. thick; (2) objects of unfavourable shape can be more effectively radiographed at 2 mev. (million electron volts) than at lower voltages; (3) stereoscopic radiography can be very effectively conducted at 2 mev. because of its penetration and the small focal spot; and (4) except for the radiography of very thick sections which require several hours' exposure at 2 mev., the use of higher voltages has no outstanding radiographic advantages.—R. A. R.

Training and Qualifications for a Career in a Commercial X-Ray and Non-Destructive Testing Laboratory. J. G. Schneeman. (Non-Destructive Testing, 1950, vol. 8, Spring Issue, pp. 13–15).

The Dissectron. Radiology by Concentrated Radiation. J. A. Hernando Perez and A. Beato Madiedo. (Metalurgia y Electricidad, 1950, vol. 14, Apr., pp. 32–35). [In Spanish]. A system of radiological devices based on new principles was recently patented by the authors. The invention, it is claimed, opens up new possibilities in the field of X-ray observations. The apparatus can detect pores and cracks down to 0·001 mm. wide in metal.

The principle consists broadly in using a beam of X-rays which, after converging at a point within the body, meets with a large photoelectric cell sensitive to X-rays; the cell registers the immediate intensity of the radiation through the body. A detailed diagram of the device is given and its use in radiotherapy is described.—R. S.

Location of Flaws by X-Rays. F. Baldi. (Metallurgia Italiana, 1950, vol. 42, Apr., pp. 133–136). A method of locating internal flaws is described. The method uses two X-ray photographs taken separately. The results obtained are satisfactory and the accuracy is more than sufficient for normal controls.—M. D. J. B.

Geiger-Müller Tubes in Industrial Radiography. O. J. Russell. (Electronic Engineering, 1950, vol. 22, Mar., pp. 94–98). A brief survey is made of the application of the Geiger-Müller tube to industrial problems such as determining the exposure for the examination of castings by X-rays and gamma rays.—R. A. R.

Symposium on the Effect of Residual Elements on the Properties of Steel—Factors Affecting the Rolling and Hot Working of Mild Steel Plate. E. C. Houston. (West of Scotland Iron and Steel Institute, Apr., 1950, Preprint, pp. 2–9). Steel plates can be irreparably ruined on the surface by heating at temperatures far short of a burning temperature. To determine whether residual alloying elements are connected with this, test pieces $6 \times 1 \times \frac{1}{4}$ in. cut from plates as-rolled were heated in an electric furnace to 1000° C. and bent first through 90° and then through 180° eight times while cooling to 700–800° C. Soaking at 1000° C. for 15 min. gave good bend-test results, but soaking for 2 hr. gave markedly inferior results. Specimens from 60 casts of steel in which the residuals nickel, chromium, copper, and tin had been determined were subjected to the bend test and the results were statistically examined. With increasing tin and chromium the number of bends showed a consistent downward trend, but the plots for nickel and copper showed large scatter which may be the result of mutual action between these alloys. Abnormal amounts of residual elements seldom occur, but cases of 1·1 and 0·9% of tin are cited. With a 10-ton ingot of steel with 1·1% of tin, great gaping cracks opened all round after about four passes in the cogging mill.—R. A. R.

The Effect of Residual Elements in Steel on the Manufacture of Steel Tubes. W. A. Smith. (West of Scotland Iron and Steel Institute, Apr., 1950, Preprint pp. 10–28). The fundamental consideration underlying the investigations reported is the formation in the scale of materials liquid at the heating temperature causing penetration round the grain boundaries. A convenient term for this is 'oxide rooting.' Iron is oxidized preferentially to nickel and copper so that these elements, which diffuse to a negligible extent in solid steel, become concentrated in the surface layers of the steel and in the inner layers of the scale. A wide range of low-melting-point solutions may then form in the presence of sulphur. Nickel sulphide melts at 797° C. and it forms with nickel a eutectic melting at 645° C. Dilution of the nickel with 50% of iron raises this eutectic temperature to 800–830° C. Cuprous sulphide melts at 1100° C. and forms with ferrous sulphide a eutectic melting at 920° C. Only a small amount of sulphur is necessary to produce a liquid phase in the scale at temperatures above the eutectic temperature concerned, the amount of the phase increasing with the amount of sulphur present. Copper in steel, even in the absence of sulphur, may lead to copper roots when the temperature is above the melting point of copper (1084° C.); in such cases nickel may be beneficial, but the presence of sulphur makes nickel injurious instead of beneficial. Chromic sulphide has a high melting point (1615° C.) and this presumably contributes to the immunity of high-chromium steels to oxide penetration round the grain boundaries.—R. A. R.

Residual Elements in Steel. H. Harris. (West of Scotland Iron and Steel Institute, Apr., 1950, Preprint pp. 29–43). Examples are described of the failure of steel in tube-making or other hot-working operations which were probably due to excessive amounts of residual copper, tin, and sulphur.

High-Temperature Steels in Steam Plant Practice. J. Glen. (Murex Limited Review, 1950, vol. 1, No. 6, pp. 106–118). The relative merits of the various steels in steam-pipe practice are considered, and the more salient features of the problem of high-temperature testing are described. With carbon steels the usual stress-relieving treatments necessary in practice do not appreciably influence the creep strength except in the case of cold-drawn steel. Due to the cold drawing, the spheroidization in service is greatly accelerated, which may seriously reduce the creep strength. By normalizing after cold drawing, the advantages of cold-drawn steel can be obtained with good creep strength. Data on the properties at high temperature of 0·5% molybdenum steel, chromium–molybdenum steel, and molybdenum–vanadium steel are discussed.—R. A. R.

Application of Electron Micrography to Cr–Mo Steels Intended for Creep at High Temperatures. P. Coheur, L. Habraken, and J. Hébert. (Société Française de Métallurgie, Oct. 6, 1949: Revue de Métallurgie, Mémoires, 1950, vol. 47, June, pp. 472–476). The creep behaviour at high temperature of a steel depends on its composition and microstructure, but cases occur where two steels apparently similar in these respects have different creep properties. Three steels, of compositions in the range 0·09–0·14% carbon, 1·94–2·85% chromium, and 0·82–1·01% molybdenum, were investigated; optical micrographs and electron micrographs were taken of (*a*) the materials before creep-testing (normalized from 925° C. and tempered at 775° C. for 6 hr.), (*b*) the heads of the creep specimens, and (*c*) parts where creep had occurred, and these are illustrated. It is concluded that the precipitation of carbides during creep is a characteristic of the steel; the carbides formed during heat-treatment are not necessarily stable at the creep-test temperature, even though this may be

225° C. below that of the initial tempering; the development of unstable carbides consists of the transformation of the ternary state into a simpler state; stresses may play a part in this development—in particular, in parts of the metals submitted to stress and for certain values of stress, new precipitations are observed, the characteristics of which are their long form and their orientation.—A. E. C.

Creep Testing by a Cantilever-Bending Method. G. T. Harris and H. C. Child. (Journal of The Iron and Steel Institute, 1950, vol. 165, June, pp. 139–144). Cantilever-bending creep testing is shown to have advantages over tensile testing for high temperatures and where the preparation of specimens must be reduced to a minimum, such as for unmachinable materials. There is good correlation between results obtained by this method and conventional testing at plastic strains up to 1·0%. For higher strains the results differ, owing partly to the constriction of tensile specimens under load, and tertiary creep is suppressed, although it can still be observed.

Evaluation of Creep Tests. N. Ludwig. (Zeitschrift für Metallkunde, 1950, vol. 41, Mar., pp. 87–91). When using creep-test data the designer must always keep in mind that they represent limiting values of elongation and fracture stress which will lead within a definite time to impermissible elongations or fractures. Using H. Eckardt's rule, it is shown that the expected elongations can be estimated, and that, for not too high temperatures, the results of the usual short-time tests can be used as a basis for calculating creep in long-time service, but not in the case of steels susceptible to hot embrittlement. For temperatures over 600° C. data from long-time tests should be collected.—R. A. R.

Alloy Casting Institute Thermal Fatigue Testing. H. S. Avery and C. R. Wilks. (Alloy Casting Bulletin, 1950, May, pp. 1–9). The paper reviews the steps leading to the method adopted at the Battelle Memorial Institute for testing the ability of alloys to withstand repeated heating and cooling. The apparatus is described and some results are given. In this test discs of the alloys 4½ in. in dia. and ¼ in. thick, drilled with four pairs of holes to act as stress raisers, were alternately heated and quenched with a jet of water in the following cycle: Heating in 5 min. to 1600° F., holding 5 min., cooling in 2 min., and holding cold 8 min. The alloys tested were 26/12, 16/35, and 12/60 chromium–nickel steels. Compared on the basis of test performance in the as-cast condition, the last behaved the best, while the other two behaved in a similar manner with the first slightly superior.—R. A. R.

High Temperature Properties of the Refractory Metals. E. R. Parker. (Transactions of the American Society for Metals, 1950, vol. 42, pp. 399–404). Data from the literature and from private sources on the melting points, densities, and room-temperature mechanical properties on 14 metals with melting points above 3200° F. are tabulated and compared with the corresponding properties of iron and nickel. Curves also show the tensile strength and elongation at temperatures up to 1800° F. of tungsten, molybdenum, titanium, iron, tantalum, and zirconium.—R. A. R.

Formability of Various Alloys for High Temperature Service. J. F. Tyrrell. (Transactions of the American Society for Metals, 1950, vol. 42, pp. 405–438). The plastic flow characteristics of 17 high-temperature alloys (eight iron base, five nickel base, and four cobalt base) were studied in tensile tests, cup tests, drop-hammer forming, and deep-drawing tests, and the results are correlated to give comparative formability ratings. Tensile tests at controlled strain rates and temperatures indicated that the mechanical equation of state was not applicable to the majority of alloys tested, possibly because of their inherent metastability. The tests did show, however, that an increase in strain rate or decrease in temperature in the range studied (0 to 200° F.) would increase the formability. Forming tests under production conditions demonstrated that precooling the blanks to sub-atmospheric temperatures appreciably improved the forming behaviour.—R. A. R.

Report on the Strength of Wrought Steels at Elevated Temperatures. R. F. Miller and J. J. Heger. (American Society for Testing Materials, 1950, Special Technical Publication No. 100). This Report is issued under the auspices of the A.S.T.M.–A.S.M.E. Joint Committee on Effect of Temperature on the Properties of Metals. It presents in graphical form (in 109 pages) the published data from tensile and creep tests on one carbon steel and 12 standard commercial alloy wrought steels at elevated temperatures, with references to the source of information. A list of the numbers and titles of the A.S.T.M. standards referred to is appended.—R. A. R.

A Laboratory Study of Intake Valve Burning. C. L. Wolfe and R. S. Spindt. (A.S.T.M. Bulletin, 1950, Feb., pp. 43–47). A progress report is presented of a study of the burning of inlet valves in which the following factors were examined: (*a*) The conditions required to make a valve burn; (*b*) the effect of the type of fuel; (*c*) the effect of the temperature of the air–fuel mixture; and (*d*) the effect of the engine running conditions. Thermally cracked type 1 petrol gave a fairly heavy, quite plastic deposit on the valve face and fillet, and 'blow-by' could be induced through this deposit by operating with a straight-run fuel. Maximum deposit on the valve fillet occurred in the critical temperature range of 150° to 200° F.—R. A. R.

The Use of Mild Steel for Service at Sub-Zero Temperatures. F. H. Keating and E. V. Mathias. (Institution of Mechanical Engineers, Mar., 1950, Advance Copy). The paper describes an investigation undertaken to determine the limiting sub-zero temperature at which mild steel may safely be used, in relation to notch brittleness. Practical experiments in which small mild-steel welded vessels were tested to destruction at − 80° C. indicated that, while such vessels ultimately fail in a brittle manner, actual rupture is preceded by a considerable amount of plastic flow. It is argued that this plastic flow gives adequate assurance that properly constructed mild-steel welded vessels will be able to absorb local over-stressing to an appreciable extent without rupture. A lower limit of − 50° C. is suggested as the operating temperature for mild-steel equipment.—R. A. R.

Properties of Cast Iron at Sub-Atmospheric Temperatures. G. N. J. Gilbert. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 964: Foundry Trade Journal, 1950, vol. 89, Aug. 10, pp. 149–161; Aug. 17, pp. 179–187). In general, grey irons show a rise in tensile strength of up to 12%, and a fall in impact strength of about 30% at − 100° C. Low-temperature treatment has no adverse effect on the subsequent room-temperature properties. A pearlitic iron containing 2% of nickel showed a fall in impact strength of 53% at − 125° C. and little change in tensile strength. The impact strength of cerium-treated nodular irons containing considerable ferrite decreases rapidly as the temperature falls below normal, the fall beginning at temperatures about normal; reductions of 90% occurred at − 100° C. A rise of 14% in the tensile strength was obtained at − 100° C. With acicular and martensitic irons the impact strength falls by up to 50% at − 100° C. The phase change in the acicular irons occurred between − 48° and − 64° C., and the martensitic material changed structure at − 26° C. The phase change was accompanied by an expansion of about 20% of that obtained in the austenitic irons. The coefficient of thermal expansion was less after the change. The nickel–copper–chromium austenitic irons W491 and W765 show a considerable rise in impact strength with decrease in temperature as the phase change is approached. At temperatures below that of the phase change the impact value falls off rapidly. The tensile strength of the Ni-Resist type of iron increased rapidly at temperatures below the phase-change temperature; the phase change in these materials is accompanied by a large expansion which proceeds with a series of audible clicks.—R. A. R.

High Temperature Reaction between Gases and Metals. A. Dravnieks and H. J. MacDonald. (Metallurgia Italiana, 1950, vol. 42, Apr., pp. 113–120). An analysis is made of the factors which influence gas–metal reactions, and the various laws which govern these reactions are examined. The different ways in which the gases act on metals are described. The growth of scale is examined; oxygen and metal diffusion through scale is discussed as well as the different factors which determine the speed of reaction. Reactions and structure disorders are examined together with the influences of reaction rate and of impurities in the gas and on the surface metal. Mechanical defects due to internal stresses are also considered. The effects of temperature on the speed of reaction and the variations in the composition of the phases and interactions between the phases in gas–metal systems are considered, and the methods of research and equipment described.—M. D. J. B.

Tool Steels for Hot Working. H. Carr. (Alloy Metals Review, 1950, vol. 8, June, pp. 2–7). The shaping and forming of hot metals necessitate the use of materials that will give long service under arduous conditions. The characteristics of tool steel for this purpose are discussed and the effects of the alloying elements cobalt, chromium, tungsten, molybdenum and vanadium, and of heat-treatment on the essential properties are considered. Many types are needed to meet all requirements. Precautions to be observed for increasing the life of the tool are given.—R. A. R.

The Effects of Zirconium in Cast Iron. C. M. Offenhauer and J. F. Collins. (Transactions of the Canadian Institute of Mining and Metallurgy, 1949, vol. 52, pp. 155–167). *See* Journ. I. and S.I., 1950, vol. 164, Mar., p. 376.

Deformation Characteristics of Five Grey Cast Irons at 400 deg. C. 500 deg. C. C. R. Tottle. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 973). Five grey cast irons made by the Meehanite process, and incorporating alloying elements, have been critically examined at 400° C. and incompletely at 500° C. The deformation at these temperatures has been measured in short-time tensile tests, 2500-hr. high-sensitivity creep tests, and stress-to-rupture tests. The ductility in the rupture tests increases as the stress is lowered and the time to fracture increases. This increase occurs in the third stage of creep. Unstressed bars, inserted in the creep furnaces, showed no growth after 10,000 hr. exposure, and no breakdown of the microstructure was observed in stressed bars, even at 500° C. Molybdenum gave the most effective resistance to deformation, chromium–copper additions being second in order of merit.—R. A. R.

Improved Test Bars for Standard and Ductile Grades of Cast Iron. R. A. Flinn and R. W. Kraft. (American Foundrymen's Society, 1950, Preprint No. 1). The A.S.T.M. Standard A-48 test bars for grey cast iron have not proved entirely satisfactory because of unsoundness and the limited representation of casting section size. Developments in nodular cast irons have accentuated the need for an improved standard, and experiments have been made with **Y** blocks. Four cast irons were used, two being of the nodular variety. No shrinkage was encountered in the **Y** blocks whilst some shrinkage was found in the standard test bars. Differences in soundness were caused by low thermal gradient (3° to 9° F./in.) in the latter compared with 38° to 61° F/in. in the **Y** blocks. Mechanical properties of test bars were lower than those of **Y** blocks of comparable cooling rate, in the case of nodular irons. Properties of irons with flake graphite were approximately the same with standard-size tensile specimens but lower with 0·505-in. dia. specimens. A series of ¼-in. to 3-in. **Y** blocks provided a greater range of cooling rates than the standard test bars. The increased cooling range of the **Y** blocks showed a wide range of mechanical properties. The ¼-in. **Y** blocks indicated the chilling tendencies of the higher strength irons and the good mechanical properties of the lower strength irons in light sections. Transverse bars machined from **Y** blocks provided more accurate and more reproducible data than the sand-cast bars because of revision of the test method and better specimen condition.—J. C. R.

INCO Writes Specs for Ductile Iron. A. P. Gagnebin. (Iron Age, 1950, vol. 165, May 4, p. 89). The International Nickel Co., Inc., suggest the following specifications for ductile cast iron :

Tensile Strength, lb./sq. in.	Yield Strength, lb./sq. in.	Elongation, %
90,000	65,000	2·0
80,000	60,000	5·0
60,000	45,000	15·0
80,000	60,000	No stipulation.

Cast specimen : 1-in. keel bar cast in dry sand.
Test specimen : Standard round test specimen, A.S.T.M. E-8, with 2-in. gauge length.
Yield-strength measurement : 0·2% offset or by dividers method at 0·5% extension under load.

Some Properties and Applications of Spheroidal-Graphite Cast Iron. A. B. Everest. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 963 : Foundry Trade Journal, 1950, vol. 89, July 20, pp. 57–64 ; July 27, pp. 95–102). The author has attempted to collect and summarize the extensive data that have now been published on the properties of nodular cast iron, and to add new data now available from practical experience of the magnesium process. A selection of castings, many for agricultural machinery, made of nodular cast iron, is illustrated, and the fields of application of these new irons are summarized.

Meehanite Castings and Nodular Meehanite. J. Sissener and R. L. Larsen. (Teknisk Ukeblad, 1950, vol. 97, Mar. 30, pp. 233–238). [In Norwegian]. The authors briefly review the work of R. Meehan and O. Smalley in developing Meehanite cast iron and present data on the microstructure and properties of this iron and of nodular Meehanite.—R. A. R.

Nodular Iron Castings or Ductile Cast Iron. J. Sissener. (Teknisk Ukeblad, 1950, vol. 97, Mar. 30, pp. 239–245). [In Norwegian]. The author reviews the literature on the manufacture and properties of nodular cast iron, and reproduces much of the published test data.—R. A. R.

Meehanite Nodular Iron Castings. V. I. Laverty. (Canadian Metals, 1950, vol. 13, Mar., pp. 30–31). This is a note on microstructure and strength properties of nodular cast irons (pearlitic and ferritic) from the Meehanite Metal Corporation. Experimental castings of a brake drum, wheelabrator cone, and injector nozzles are illustrated, many others are being tested.—E. C.

Data on Corrosion- and Heat-Resistant Steels and Alloys—Wrought and Cast. R. Franks, J. W. Juppenlatz, V. N. Krivobok, F. L. LaQue, F. P. Peters, and E. A. Schoefer. (American Society for Testing Materials, 1950, Special Technical Publication No. 52-A). This publication contains 79 pages of tables giving the compositions and properties of (*a*) wrought corrosion- and heat-resisting chromium and chromium–nickel steels, (*b*) cast corrosion-resisting alloys with 11 to 30% of chromium and up to 4% of nickel, and with 18 to 30% of chromium and 8 to 22% of nickel, and (*c*) cast heat-resisting alloys containing chromium and nickel.—R. A. R.

Contribution to the Study of Acid-Resisting Silicon Irons. R. Lefébure. (Métaux et Corrosion, 1950, vol. 25, Jan., pp. 9–29 ; Feb., pp. 44–53 ; Mar., pp. 67–83). From 12·5% to 20% silicon increases the corrosion resistance of iron. Above 20% there is no further increase ; indeed, brittleness increases to such an extent that the alloy would have no practical value. The paper discusses the constitution and properties of these and some special silicon irons. The work is divided into four parts : (1) The iron–silicon diagram and the constitution of binary stainless alloys ; (2) manufacture, and physical and chemicophysical properties ; (3) mechanical and chemical properties ; and (4) conclusions and applications.

The constitution of the binary alloys is considered in relation to heat-treatment, and the structure of the more complex alloys is reviewed. The combination of iron and silicon gives rise to considerable contraction and a marked increase in true density. The 18% silicon alloy shows the maximum electrical resistance and sensitivity to the action of a magnetic field at ordinary temperatures. In the same conditions the 13% silicon alloy has the lowest resistance. The electric resistance, magnetism, and dilatation of a binary iron–silicon alloy increase with the silicon content, whilst the presence of additional elements causes a drop in physical properties, except the electrical resistance.

Microhardness tests on the simple and complex alloys were made. A 13·87% silicon alloy, annealed for 10 hr. at 940° C. gave 48·4 Rockwell C (480 Brinell) ; an 18·22% silicon alloy annealed for 2 hr. at 1090° C. gave 51 Rockwell C (510 Brinell) ; a complex alloy annealed for 2 hr. at 1100° C. gave 56·6 Rockwell C (567 Brinell). An Amsler tensile machine equipped for compression was used for the compression test and a Guillery machine for the shear test.

The main characteristics of these alloys are great hardness and brittleness, and low tensile strength. The effects of additions made to the binary alloy to improve the mechanical properties are reviewed. Tests for measuring the corrosion resistance are outlined and data on the action of mineral and organic acids, bases, and salts, are given. Finally, the melting, casting, and applications (mainly chemical plant and anodes for use in acid sulphate baths) are briefly described.—R. S.

Alloy Steels. E. Ineson. (Machinist, 1950, vol. 94, Apr. 15, pp. 586, 588). The author shows that scarcely any alloys were available at the beginning of the century and then discusses the advances which have led up to the wide range of alloy steels available today.—R. F. F.

Alloy Steel Castings. R. T. Rolfe. (Iron and Steel, 1950, vol. 23, Feb., pp. 49–50). The compositions and mechanical test values from eight British Standards, two Ministry of Supply Aircraft Material Specifications and one British Admiralty Specification, for alloy steel castings and 13% chromium steel castings are given. Apart from the British Admiralty specification, there are no British specifications whatever for castings of straight chromium steel, and the urgent need for more specifications for these steels and the austenitic stainless steels is pointed out.—R. A. R.

METALLOGRAPHY

An Improved Polarizing Microscope. IV—The Federov Stage (Three-Axis). A. F. Hallimond and E. W. Taylor. (Mineralogical Magazine, 1950, vol. 29, June, pp. 150–162). As far as the authors are aware the only three-axis stage for a polarizing microscope is made by a San Francisco firm to a design which in all other respects closely follows the existing four-axis pattern. In the model described, by fixing the tilting axis A_2 (the axes are numbered A_1 to A_4 from within outwards) at right angles to A_4 it has been possible to eliminate collisions between the Wright arcs and the objectives. Consequently the arcs have been fixed upright, without hinges, and the lock to the spindle A_2, universally recognized as inefficient, has been replaced by clamps that slide on the Wright arcs and give complete stability when closed. Other improvements are described.—R. A. R.

Electronic Microscope with Magnetic Lenses. R. Schmidt. (Métaux et Corrosion, 1949, vol. 24, Oct., pp. 235–238). The Philips magnetic lens microscope, combining a variable magnification microscope with an electronic diffractograph is described. Besides the usual objective and projector lenses, the microscope has a variable magnification lens and a diffraction lens. Varying the combination of these lenses permits a very wide range of magnification to be obtained and enables the different parts of the object to be studied by electronic diffraction. This is done without modifying the position of the object or the lenses.—R. S.

The Electron Microscope in Metallurgy. A. L. Ellis. (American Iron and Steel Institute, May, 1950, Preprint). Investigations of the same carbide particles with the light and the electron microscope, and of the structure of martensite with the electron microscope are reported. Measurement of several pairs of light and electron micrographs showed that the disagreement between the mean diameters of the carbide particles was approximately + 2%. Several electron micrographs of martensite are shown, some of which indicate the effect of tempering.—R. A. R.

An Autoradiographic Method for Studying Segregations in Steels. A. Kohn. (Comptes Rendus, 1950, vol. 230, June 19, pp. 2201–2203). Methods of using radio-active tracer elements to reveal segregation in steels are outlined very briefly and a few results so obtained are presented.—A. E. C.

A Metallographic Technique for Cemented Carbides. W. H. Bleecker. (Iron Age, 1950, vol. 165, May 25, pp. 71–74). The necessary flatness for high magnification can be obtained by grinding the specimen with a 220-grit resin-bonded diamond wheel on a surface grinder. Final polishing is carried out with 6-micron and 1-micron diamond compounds on a standard lap using kerosene as a lubricant. A suggested phase nomenclature is put forward.—A. M. F.

The Chemical Nature of Metallic Surfaces Polished Electrolytically, and Its Practical Importance. P. A. Jacquet and M. Jean. (Comptes Rendus, 1950, vol. 230, May 22, pp. 1862–1864). The surfaces of copper, zinc, and magnesium polished electrolytically in phosphoric acid solutions can retain traces of a substance containing phosphorus. Iron polished in a mixture of phosphoric and chromic acids retains no compounds rich in phosphorus or in chromium, but is probably covered with a layer of oxide. These results are discussed from the point of view of certain properties peculiar to metals polished electrolytically.—A. E. C.

Caustic Etching Detects Fatigue Damage. P. W. Boone. (Iron Age, 1950, vol. 165, May 18, pp. 99–100). Caustic etching for the detection, with only low magnification, of fatigue damage in aluminium alloys is described. A hot 1 : 1 hydrochloric acid etch can be used similarly for steel. A. M. F.

Specific Etching Colours on Iron–Silicon Alloys—A New Rapid Method for Detecting High-Silicon Iron–Silicon Alloys. E. Fitzer. (Werkstoffe und Korrosion, 1950, vol. 1, Mar., pp. 103–104). After reviewing the literature on the colour-etching of iron–silicon alloys, a new electrographic method is reported with which iron–silicon solid solutions containing at least 8% of silicon in a metallographic specimen can be rapidly distinguished. The method consists of an anodic oxidation of the alloy followed by treatment with methylene blue.—R. A. R.

Internal Structure of the Solid State. C. A. Zapffe. (Revue de Métallurgie, Mémoires, 1950, vol. 47, May, pp. 329–342). The author gives an account of his fractographic researches—investigations of fractured surfaces. He discusses fundamental types of fracture, crystallographic weaknesses, and weaknesses due to imperfections, presents observations made on antimony and bismuth, and touches on commercial applications of fractography (examples of fractographs of ship plate and steel welds are reproduced). In conclusion he puts forward a new theory of the solid state.—A. E. C.

Metallographic Applications of an Improved Technique for Obtaining Laue Diagrams. A. Guinier and R. le Roux. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Mar., pp. 149–157). The method and its theoretical basis were described in detail in an earlier paper in *Acta Crystallographica*, 1949, vol. 2, p. 133. In the present article the procedure is outlined; the essential feature is the use of a very small source of radiation and the omission of a collimating system. The appearance of the diagrams and the use of a linear source instead of a point source are discussed. By way of example the use of the method for examining deep-drawing steel sheets is described; the Laue diagrams are correlated with the relative micrographs.—A. E. C.

Textures and Their Effect on Sheets of 50% Nickel–Iron. E. Schmid and H. Thomas. (Zeitschrift für Metallkunde, 1950, vol. 41, Feb., pp. 45–49). Specimens of 50/50 nickel–iron sheet 6 mm. thick were cold-rolled down to 0·35 mm. and these were etched on both sides to prepare pieces 0·07 mm. thick for good X-ray penetration. Whilst the strength of the hard sheet was only slightly related to the rolling direction, the elastic modulus in the 45° direction was only about 75% of that in the rolling and transverse directions. Regions with the cube faces at right angles and parallel to the sheet surfaces were observed only to a very limited extent. The existence of spinel-twinning in recrystallized sheet having these regions was detected by X-rays. By systematically studying the beginning and the spread of recrystallization an attempt is made to explain the recrystallization texture of cubic face-centred metals.—R. A. R.

The Constitution of Alloys. R. L. Cunningham. (American Society for Metals: Canadian Metals, 1950, vol. 13, Feb., pp. 10–13, 49). Phase diagrams for binary alloys are explained and examples of diagrams for non-ferrous alloys are shown to illustrate what can be learnt from them.—R. A. R.

Kinetics of the Decomposition of Austenite in Iron–Carbon–Nitrogen Alloys. J. Pomey, R. Coudray, and F. Goutel. (Comptes Rendus, 1950, vol. 230, June 26, pp. 2298–2300). The study of the isothermal decomposition of austenite in iron–carbon–nitrogen alloys in the form of hardened and homogenized iron wire shows that nitrogen has a considerable retarding effect, both on the rate of nucleation of α-iron and on the rate of linear crystallization. The Ar_3 point is also lowered by nitrogen.

To study the simultaneous effects of carbon and nitrogen on the rate of isothermal decomposition of austenite, tests were carried out on iron wire 0·5 mm. in dia., hardened at 810° C. in a gaseous atmosphere consisting of CO 32·5–33·8%, N_2 35·2–36%, C_5H_8 0·3–0·1%, NH_2 0·8–0·3% by volume.

The wire, in bundles, was austenitized for 3 min. at 850° C. and quenched in a salt bath at the decomposition temperature. The variation in magnetism in relation to time was noted in a magnetic balance. Since the magnetic susceptibility of the various constituents was known, the variation in the rate of the decomposition of austenite was deduced in relation to time. Thus, curves were produced for equal rates of decomposition as a function of temperature and time.—R. S.

Thermomagnetic Transformations of Iron–Carbon–Nitrogen Alloys. J. Pomey, F. Goutel, J. Moulin, and R. Coudray. (Comptes Rendus, 1950, vol. 230, June 19, pp. 2196–2198).

A series of homogeneous iron–carbon–nitrogen alloys with up to 1·5% of nitrogen and 1·25% of carbon was prepared by the gaseous cementation and diffusion of dead mild-steel wires 0·5 mm. in dia. Thermomagnetic examination revealed the reversible transformation of the austenite into carbide (Fe_3C) and nitride (Fe_4N). This eutectoid transformation started at 595° C. on heating, as in iron–nitrogen alloys, but it was completed at a temperature lower than that for iron–nitrogen alloys or that for iron–carbon alloys.—A. E. C.

Equilibrium Diagram of the Order ⇌ Disorder Transformation in Ferronickels in the Neighbourhood of Ni_3Fe. E. Josso. (Comptes Rendus, 1950, vol. 230, Apr. 17, pp. 1467–1469). The differential dilatometric method was applied to the determination of the critical temperature of the order/disorder transformation in pure ferronickels of composition approximating to Ni_3Fe. The equilibrium diagram of this transformation between 68 and 80% of nickel is presented. A. E. C.

High-Temperature X-Ray Study of the System Fe_3O_4–Mn_3O_4. H. F. McMurdie, Barbara M. Sullivan, and F. A. Mauer. (Journal of Research of the National Bureau of Standards, 1950, vol. 45, July, pp. 35–41). A series of compositions in the system Fe_3O_4–Mn_3O_4 was prepared and examined at high temperatures by X-ray diffraction methods. Although Fe_3O_4 and Mn_3O_4 form a continuous series of substitutional solid solutions stable at room temperatures, those compositions containing less than 60% of Mn_3O_4 are cubic, of the spinel type, and the rest are tetragonal. Those compositions that are tetragonal at room temperature pass through a two-phase region when heated and acquire the cubic spinel-type structure at high temperatures. The temperature range of the two-phase (ex-solution) region varies with composition. The relation to this system of the minerals vredenburgite and hausmannite is discussed.

The Uranium–Iron System. J. D. Grogan. (Journal of the Institute of Metals, 1950, vol. 77, Aug., pp. 571–580). The paper describes an examination of the uranium end of the uranium–iron system and a brief survey of the remainder. The solubility of iron in solid uranium increases with temperature from about 0·004 wt.-% (0·018 at.-%) at 600° C. to about 0·35 wt.-% (1·5 at.-%) at 805° C., the temperature at which the solid-solubility curve meets both the solidus and a peritectic horizontal line where liquid reacts with solid uranium to form the compound U_6Fe. In an appendix C. J. Birkett Clews reports on an X-ray examination of uranium–iron alloys and discusses the structure of UFe_2. R. A. R.

The Quaternary System Aluminium–Iron–Cobalt–Nickel, with Reference to the Role of Transitional Metals in Alloys. G. V. Raynor and M. B. Waldron. (Proceedings of the Royal Society, Series A, 1950, vol. 202, Aug. 7, pp. 420–438). The investigation was conducted to examine how adequately the constitution of the hitherto unexamined aluminium-rich aluminium–iron–cobalt–nickel alloys could be deduced from a knowledge of the three relevant ternary systems, in the same way as the main features of the aluminium–cobalt–nickel diagram were deduced by Raynor and Pfeil.

The results, which are discussed, confirm previous suggestions that the intermetallic compounds formed by aluminium and transitional metals may, if sufficient aluminium is present, be regarded as analogous to electron compounds, with absorption of electrons by the transitional metal atoms occurring. The theory may be used, in favourable cases, to predict quantitatively the forms of uninvestigated complex equilibrium diagrams.—R. A. R.

CORROSION

Corrosion of Metals. DIN 50 900. (Werkstoffe und Korrosion, 1950, vol. 1, Mar., pp. 112–115). This tentative German standard defines the German terms relating to corrosion and corrosion testing.—R. A. R.

The Corrosion of Steel in Estuarine Tropical Waters. S. A. Main and T. H. Arnold. (Journal of The Iron and Steel Institute, 1950, vol. 165, July, pp. 268–278). The corrosion of various steels in estuarine tropical waters at Freetown, Sierra Leone, has been investigated, and the result compared with exposure in ordinary tropical sea water at Takoradi on the Gold Coast. The results are interpreted in the light of the work of other investigators, in particular those of the Sea Action Committee of the Institution of Civil Engineers. Some of the operative factors concerned in the corrosion, *e.g.*, molluscs, sulphate-reducing bacteria, etc., are discussed.

Neutralization as a Means of Controlling Corrosion of Refinery Equipment. E. Q. Camp and C. Phillips. (Corrosion, 1950, vol. 6, Feb., pp. 39–46). The paper summarizes the results obtained by the injection of sodium hydroxide, ammonia, and lime to prevent the corrosion of oil-refinery equipment. Ammonia has been injected into distillation, cracking, gas absorption, debutanization, and steam systems, and sodium hydroxide and lime into cracking units. Successful results were obtained. The injection equipment is described.—R. A. R.

The Use of Ammonia in Control of Vapor Zone Corrosion of Storage Tanks. F. T. Gardner, A. T. Clothier, and F. Coryell. (Corrosion, 1950, vol. 6, Feb., pp. 58–65). The interior of storage tanks for crude oils containing hydrogen sulphide is subject to heavy corrosion above the liquid level and laboratory and full-scale tests have shown that ammonia can be successfully used as an inhibitor. In tanks of 55,000-barrel capacity the efficiency of protection gradually increased from 16% to almost complete protection by increasing the injection of the inhibitor from 1·4 to 12–15 lb./day into each tank.

Causes of Corrosion in Airplanes and Methods of Prevention. N. H. Simpson. (Corrosion, 1950, vol. 6, Feb., pp. 51–57). The author points out the types of corrosion which may occur on modern aircraft and discusses the latest methods of combating this. Some corrosion problems relating to pressure cabins and high-speed flight are considered.—R. A. R.

Electrolysis Experiences on 115 kV. High Pressure Oil Filled Pipe Type Cable Installation in New Orleans. S. E. Trouard. (Corrosion, 1950, vol. 6, Feb., pp. 66–71). An account is given of the cathodic protection measures taken to deal with corrosion arising from electrolysis in 6⅝-in. coated steel pipeline, electrically continuous throughout its length of 11 miles, housing cables for a three-phase 115 kV. circuit, the pipe being filled with a special oil at 200 lb./sq. in. The electrolysis problems encountered were unique in that the line traversed several areas of strong stray current from electric railways. R. A. R.

Rectifiers and Galvanic Anodes for Cathodic Protection. A. L. Stegner. (Proceedings of the American Gas Association, 1949, pp. 669–673). The factors governing the selection of a system of cathodic protection for buried pipelines are considered; this is followed by brief descriptions of rectifier systems and galvanic anode systems on buried gas mains in Texas, Louisiana, and Kentucky.—R. A. R.

Caustic Cracking: Stress-Corrosion Tests in Sodium Hydroxide Solutions at Elevated Temperatures. C. D. Weir. (Institution of Mechanical Engineers, Feb., 1950, Advance Copy). An apparatus specially designed for stress-corrosion investigations at high temperatures is described and the results of tests reported. Hollow specimens were inserted into the base of an autoclave and loaded by a system of levers. Accurate notch forms could be produced on the external surface of the specimen in contact with sodium hydroxide solution. The failure of notched specimens could be produced rapidly and consistently, but homogeneously stressed specimens were immune. The fractures were intercrystalline and typical of those occurring in practice. Dilute solutions were much less effective than those of high concentration. Silica in the solutions exerted no appreciable influence. Neither the addition of tannin nor the use of fine-grain steels was completely effective in preventing intercrystalline failure, though with the latter, increased resistance was noted in some cases. Cathodic polarization was protective whilst anodic polarization did not prevent, and possibly hastened, failure.—R. A. R.

A New Theory for Corrosion Fatigue. F. Lihl. (Berg- und Hüttenmännische Monatshefte der Montanistischen Hochschule in Leoben, 1950, vol. 95, Feb., pp. 25–34). Having reviewed the previous important experimental results relating to corrosion fatigue, the author discusses some of his own X-ray investigations of microstructures which, by reason of the similar changes in the X-ray picture when the static elastic limit is exceeded and when fatigue conditions prevail, point to a relationship between the crystallographic phenomena occurring under the two kinds of stress. This

knowledge and certain aspects of the precipitation during the cooling of a metal or alloy form the basis of an interpretation of the corrosion-fatigue fracture. The reduction in the fatigue strength of steel in corrosive conditions is due to intercrystalline corrosive attack which destroys the deformation resistance set up by the lattice-like precipitation within the grains.—R. A. R.

Correlation of Accelerated Weathering Machines. R. W. Hill, G. S. Cook, and W. E. Moyer. (A.S.T.M. Bulletin, 1950, Feb., pp. 32–43). This report covers an investigation to correlate the results of exposure tests on painted panels obtained using two weathering machines, namely, the National Carbon X1A Accelerated Weathering Machine in which the panels are exposed to filtered light from a carbon arc and 18 min. of water spray every 2 hr., and the Atlas Twin Arc Weatherometer in which the panels receive water spray intermittently and light similar to sunlight continuously. Several possible bases of correlation were examined. The one chosen was the amount and type of change of colour of the paint.—R. A. R.

ANALYSIS

Use of the Pile for Chemical Analysis. C. O. Muehlhause and G. E. Thomas. (Nucleonics, 1950, vol. 7, July, pp. 9–17, 59). In two-component systems, elements that are sometimes difficult to identify reveal themselves readily after bombardment by nuclear radiation. A laboratory with a pile, cyclotron, betatron, or linear accelerator can make such analyses. The theory of the method of applying neutron radiation to the identification of elements in two-component systems is explained.—R. A. R.

Bibliographical Note on the Chemical Analysis of Metallurgical Products. M. Jean. (Chimie Analytique, 1950, vol. 32, June, pp. 133–138); July, pp. 162–167). The author discusses publications on the analysis of steels and ferroalloys, mainly since 1944, though some previous important work is mentioned, especially regarding the analysis of gases in steels. In some cases, a brief reference is made to principles of a certain method, but this note endeavours rather to indicate the treatment by the various authors reviewed. The first two papers of these studies cover publications concerning methods of analysis for carbon, silicon, manganese, sulphur, phosphorus, copper, nickel, chromium, molybdenum, wolfram, cobalt, and arsenic. A bibliography of 199 items is given.—R. S.

Polarographic Analysis in Metallurgy. G. Semerano. (Metallurgia Italiana, 1950, vol. 42, Apr., pp. 121–128). After a brief description of the polarographic method, the author reviews the various methods of quantitative analysis and examines in detail an absolute method recently developed. The limits of accuracy and field of application of the method are given. The cases in which the polarographic method has proved particularly interesting for metallurgical study are: (1) Analyses of pure metals and alloys; (2) analyses of protective coatings; and (3) the study of corrosion phenomena. The metals examined are classified according to the predominant elements.—M. D. J. B.

Photo-Multiplier Tubes, Their Use and Their Applications in Spectro-Analysis. P. Traynard. (Revue de Métallurgie, Mémoires, 1950, vol. 47, June, pp. 409–420).

The Use of the Spectroscope in the Steel Industry. E. O. Waltz. (American Iron and Steel Institute, May, 1950, Preprint). Data are presented on the saving in man-hours achieved by using the spectrograph for routine analyses to control heats as compared with wet chemical methods, and these are discussed. The use of the spectrograph for determining or identifying undesirable elements in refractories is briefly referred to.—R. A. R.

Experiences in the Application of Spectrographic Analysis in the Grey-Iron Foundry. E. J. Ronnie and M. M. Hallett. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 965: Foundry Trade Journal, 1950, vol. 89, Aug. 3, pp. 115–124). Two years' experience of the operation of a spectrographic laboratory at the iron foundry of Sheepbridge Engineering Ltd., Chesterfield, has shown that the spectrograph can be applied to the analysis of practically every type of cast iron, including high-alloy irons of the austenitic and 33% chromium types.

The applicability of the spectrograph, its accuracy, the staff and space needed for its operation, cost, and its advantages and disadvantages are discussed in the first part, while the second part gives a more detailed account of the precise methods adopted.—R. A. R.

An Ultraviolet Multiplet Table. Charlotte E. Moore. (National Bureau of Standards, Apr. 28, 1950, Circular No. 488, Section 1). The earlier astrophysical multiplet table has proved inadequate because of its limited range of wavelength; in order to make more complete data available the present extension to it is presented. Section 1 includes selected spectra of the first 23 elements of the Periodic Table, namely, hydrogen, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine, argon, potassium, calcium, scandium, titanium, and vanadium.

Spectroscopic Phenomenon Produced by the Tesla Spark. H. Triché. (Comptes Rendus, 1950, vol. 23, May 8, pp. 1659–1661). When using a Tesla spark of which the emission is localized in the neighbourhood of the electrodes, the spectrum of iron sulphide differs from that of pure iron if the specimen is moved about during the exposure. If, however, the spark is kept for some time at the same spot before making the exposure the iron sulphide spectrum will approximate to that of pure iron. Surface elimination of sulphur is suggested as the cause. The relative strengths of various lines in the spectra of the two substances are discussed.—A. E. C.

Colorimetric Determination of Aluminium in Steels. J. Carroll, I. Geld, and G. Norwitz. (American Foundryman, 1950, vol. 17, Apr., p. 105). A rapid and accurate colorimetric method is proposed for the determination of aluminium in steels. A composite aluminon reagent is used. The procedure is given in detail.—R. A. R.

Method for the Estimation of Small Amounts of Carbon in Steel. K. Gardner, W. J. Rowland, and H. Thomas. (Analyst, 1950, vol. 75, Apr., pp. 173–179). A brief survey is given of the methods available for the determination of small amounts of carbon (less than 0·03%) in steel. The method described utilizes a combustion procedure in which the carbon dioxide produced is absorbed in baryta solution. The decrease in electrical conductivity of this solution is related to the carbon content. The difficulties which arise are discussed and necessary precautions are described. A device for the introduction of the sample into the combustion zone, without ingress of air, is shown. Adsorption of carbon dioxide by the pre-ignited boats is avoided by storing over soda asbestos. A high efficiency of absorption in the baryta solution is attained by the use of a cell having a long absorption path and by addition of a non-ionic wetting agent, Lissapol N, to the absorbing solution. For steels containing less than 0·03% carbon the average deviation from the mean value does not exceed $\pm$ 0·0005%. The determination occupies 40 min., half the time needed for similar methods. The apparatus can be constructed from laboratory equipment, and is robust and comparatively inexpensive. The method has been in satisfactory operation for over two years, and the results compare favourably with those obtained by the standard low-pressure method.

HISTORICAL

Early Manufacture of Tinplate in England. (Tin and Its Uses, 1950, Apr., p. 4). Among papers presented to the Kidderminster Public Library is a letter bearing on the manufacture of tinplate in England at an earlier date than has hitherto been recorded. A facsimile of the letter with a version in modern spelling is reproduced. The letter, dated Sept. 12, 1623, is by John Tilte to his uncle. He states that he and another man, using a mill belonging to the Earl of Southampton, "have upon a trial wrought up one ton of iron and have made as good plate as any that comes from beyond the seas. We can tin them ourselves . . ."—R. A. R.

The Achievement of Sidney Gilchrist Thomas. M. Davies. (British Steelmaker, 1950, vol. 16, Apr., pp. 160–165). A brief account is given of the life of Sidney Gilchrist Thomas with notes on the consequences of his introduction of basic linings for Bessemer converters which enabled iron from the phosphoric ores of Britain and the Continent to be blown, the phosphorus passing into the basic slag.—R. A. R.

Sidney Gilchrist Thomas. J. Mitchell. (Journal of The Iron and Steel Institute, 1950, vol. 165, May, pp. 1–8). At this commemorative lecture an account was given of the work of Sidney Gilchrist Thomas (1850–1885) in a manner which stresses his character and the thoroughness with which he successfully solved the problem of dephosphorizing pig iron on an industrial scale by lining the Bessemer converter with basic material.—R. A. R.

The History of Greenings. (Wire Industry, 1950, vol. 17, Mar., pp. 263–266; Apr., pp. 353–357; May, pp. 425–427). The article consists of extracts published from the book "A History of Greenings, 1799–1949" giving an outline of the history of N. Greening & Sons Ltd., Warrington, manufacturers and weavers of wire.—R. A. R.

Commemoration of the Centenary of the Birth of Floris Osmond, 1849–1912. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Feb., Supplement, pp. 1–64). The centenary of the birth of Floris Osmond, the 'father' of metallography, organized by the Société Française de Métallurgie, was celebrated in the Sorbonne, Paris, on Friday, 7th October, 1949, under the patronage of the President of the French Republic; M. Louis de Broglie, of the Académie Française and Secretary of the Académie des Sciences, presided. Commemorative addresses were delivered by General P. Nicolau, President of the Société Française de Métallurgie, by M. A. Portevin, Membre de l'Institut, and by M. Louis de Broglie. Professor Carl Benedicks, on whom was conferred the first "Grande Médaille Osmond," inaugurated by the Société Française de Métallurgie to mark the occasion, delivered a lecture on "The Developments of the Work of Floris Osmond."—A. E. C.

ECONOMICS AND STATISTICS

Development of Metallurgy in Spain. (Boletin Minero e Industrial, 1950, vol. 29, May, pp. 269–270). [In Spanish]. The establishment of a ten-year plan for the Spanish metallurgical industries was recommended by a recent Presidential decree. The output of finished products should be increased by 600,000 tons per year. This is to coincide with the Schuman plan. Spanish production figures show an increase during 1947 and 1948 to 609,600 tons of iron, 719,000 tons of steel, and 459,500 tons of rolled products. The effects of electric power restrictions are discussed. It is hoped to complete all the new coke-oven batteries and the new ore preparation and sinter plant of the Altos Hornos de Vizcaya by 1953. Other projects for expansion in Aviles, Sagunto, the Duro Felguera plant, Echevarria, Mieras, and Nueva Montana are briefly surveyed.—R. S.

The Rôle of the Electrical Industry in the Industrialization of Spain. J. L. Redonet Maura. (Dyna, 1950, vol. 25, Apr., pp. 131–150). [In Spanish]. The article summarizes the possibilities of the generation of electric power in Spain. Details are given of the hydroelectric potential and of the production of electric power from anthracite, pit coal, and lignite. The necessity for a Spanish 'market' for electric power and the improved utilization of present power sources are discussed. A good map of the main hydroelectric systems, carboniferous deposits, and centres of consumption in Spain is provided. The practical hydroelectric potential is of the order of 9,000,000 kW. (32^9 kWh./annum). Electricity production from fuel must be limited to the use of low-grade fuels to produce about 29^9 kWh./annum. Measures for the exploitation of new sources are discussd.—R. S.

Spanish Special Steels. A. G. Sanmartin. (Boletin Minero e Industrial, 1950, vol. 29, Apr., pp. 197–200). [In Spanish]. This is a very general survey of the need for special steels and for a proper knowledge of their properties in order to apply the correct quality for a given purpose. Some elementary remarks are made on the importance of experience in judging the significance of such data as Jominy tests and **S** curves.

Finally, the author emphasizes the fact that excellent special steels can be made in Spain, though difficulties are encountered in the lack of ferro-alloys and of adequate modern plant for the production of stainless and heat-resisting steel sheets and strip. It is necessary for Spain to make special steels in greater quantities before the necessary experience to maintain quality is gained.—R. S.

The Manufacture of Special Steels in Spain. Luis Barreiro. (Boletin Minero e Industrial, 1950, vol. 29, Apr., pp. 183–196). [In Spanish]. Production figures are given for Spanish special and electric steels for 1941 to 1948. A broad classification of structural steels, tool steels, and stainless and heat-resisting steels is made, and the author gives an elementary description of their properties.—R. S.

The Spanish National Plan of Industrialization. (Revista de Ciencia Aplicada, 1950, vol. 4, Mar.–Apr., pp. 170–173). [In Spanish]. The main points of the 1950–51 plan for industrialization as outlined by the Spanish Ministry of Industry and Commerce are given. Coal, electric power, mining, chemical and metallurgical industries, agriculture, and transport form the basis of this plan. The main undertakings in these spheres are mentioned.—R. S.

The Development of the Iron and Steel Industry in India. E. V. Parkinson. (Journal of the Royal Society of Arts, 1950, vol. 98, June 30, pp. 668–685). The paper describes developments in the Indian Iron and Steel Industry which have taken place since 1927. Three important factors influenced the industry: (1) The depression in the world's markets in 1932–34; (2) the war of 1939–45; and (3) the political changes during 1947–50. Raw materials and rolled products are discussed with production data, and brief accounts are given of the activities of the individual concerns producing or finishing steel.—R. A. R.

Electro-Metallurgical Aspects of Brazil. J. Sanz y Diaz. (Metalurgia y Electricidad, 1950, vol. 14, May, pp. 39–40). [In Spanish]. Some statistics relating to steel output in Brazil are given. Mention is made of some special products, including seamless tubes and tinplate, and of the production of chromium, manganese, tin, and aluminium. No technical details of electrometallurgical processes are given.—R. S.

New Steelworks in Argentina. (Dyna, 1950, vol. 25, May, p. 197). [In Spanish]. Construction of a new steel and tinplate plant by Armco Internacional was recently begun at San Nicolas, Buenos Aires province, to produce 650,000 tons per year with a subsequent output of up to 1·5 million tons yearly. North American and British coal will be imported. Plenty of local limestone is available but ferro-manganese will have to be imported. No technical description of the plant is given.—R. S.

MISCELLANEOUS

Electrothermal, Electrolytic, and Electrostatic Processes, and Electric Welding. J. W. Cuthbertson. (Proceedings of the Institution of Electrical Engineers, 1950, vol. 97, Part I, Mar., pp. 43–60). A review is presented of developments over the past ten years in electrothermal processes including electric furnace practice and technique, electrolytic extraction, electrodeposition, and in electrostatic processes, and electric welding.—J. C. R.

Melts Steel in Oxygen/City-Gas-Fired Crucible Furnace. J. M. Barrabee. (American Foundryman, 1949, vol. 16, Dec., pp. 51–53). A description is given of a laboratory furnace, fired with oxygen and town gas, for the rapid melting of up to about 10 lb. of steel. The furnace consists of a sheet-metal barrel 20 in. in dia. × 35 in. high, lined with $1\frac{1}{2}$ in. of alundum, the whole being surrounded by gypsum in an outer container. The gas entered at the bottom through a $1\frac{1}{2}$-in. pipe, and the oxygen was supplied through four $\frac{1}{4}$-in. pipes set tangentially at 90° spacing, an arrangement which gave excellent mixing.—R. A. R.

Iron and Steel Research in England. Sir Charles F. Goodeve. (Jernkontorets Annaler, 1949, vol. 133, No. 9, pp. 305–322). [In Swedish]. An account is given of the formation, organization, and activities of the British Iron and Steel Research Association.—R. A. R.

One Hundred Years of French Scientific and Technical Contribution to Mining and Metallurgy. P. Bastien. (Mémoires de la Société des Ingenieurs Civils de France, 1948, Sept. pp. 597–623). A survey is presented of developments in mining and metallurgy over the past hundred years, with special reference to the part played by French scientists and industrialists.—J. C. R.

International Collaboration in Metallurgy. R. Seligman. (Société Française de Métallurgie, Oct. 3, 1949: Revue de Métallurgie, Mémoires, 1950, vol. 47, Mar., pp. 187–191).

LÄTZIG, W. "*Läppen. Die Grundlagen und ihre praktische Anwendungen.*" 8vo, pp. 185. Illustrated. Munich, 1950. Carl Hanser-Verlag. (Price DM 11.20).

This book deals with the lapping of metallic materials, excepting tool tips. Special importance is attached to practical hints at the risk of entering into spheres not directly associated with lapping. Many of these hints are based on workshop experience and have not been submitted to the test of scientific examination and research.

The principles of the lapping process (speeds, pressures, power consumption, etc.) are described. Surface properties and the shapes of material and their influence on the lapping process are examined. Carbon steel, case-hardening steel, oil-hardening steels, hard metals, cast iron, and softer materials are considered in relation to their suitability for lapping.

Chapter three deals with the characteristics of the materials used for laps, and the machining and grooving of laps. Chapter four covers types of lapping abrasive, selection of granulation, lapping fluids, mixtures for hand and machine lapping, and the wet and dry charging of abrasives.

Chapters five and six describe the many variations of hand and machine lapping, including flat and round lapping (internal and external), conical and spherical lapping, thread lapping, etc.

The cleaning, greasing, testing, and measuring of parts are described.

A chapter is included on the kinematics of the various lapping processes, and finally there is a chapter on those machining processes which border on the sphere of lapping, *e.g.*, fine grinding, lap grinding, and polishing.

There is a bibliography with 140 references and a useful index.—R. SEWELL.

LICKTEIG, E. "*Schraubenherstellung.*" Second edition. 8vo, pp. xiii + 244. Illustrated. Düsseldorf, 1950. Verlag Stahleisen m.b.H. (Price DM 26.–)

Screws are not merely an auxiliary machine part but are often highly stressed in a complicated manner. In spite of mass production, screws have quality which is to be traced back to the materials. The screw industry is one of the most important intermediate industries between heavy steel and engineering.

This second edition covers the latest knowledge of screw production in Germany and abroad. The borderline between screw manufacture proper and general machining is difficult to draw. The sections on testing and standards have been shortened since many special German standards have been cancelled.

The main sections of the book cover : The history of the development of the screw ; applications ; stress and fatigue properties ; testing of screws and screw material ; hot forging, cold forming, and machining from bar ; production of heads, threads, and nuts ; auxiliary processes such as pointing and slipping ; heat-treatment ; special treatments including anti-corrosive coatings ; carburizing, nitriding, and flame-hardening ; economic and technical consideration of the development of screw manufacture from machining methods to hot and cold deforming methods ; and German standards for screws, threads, nuts, and spanners, including those for railways, boilers, and tools, with a survey of British and American standards.

The final chapter surveys patents covering screw design, safety devices, stresses, and manufacturing methods. A bibliography of 155 items is appended.—R. SEWELL.

PÜTZ, F. "*Werkzeug-Handbuch über Schneidwerkzeuge für die Metallbearbeitung.*" 8vo, pp. 418. Illustrated. Munich, 1950. Carl Hanser-Verlag. (Price DM 34.–)

The lack of suitably edited literature on cutting tools gave rise to the present book.

The materials used for toolmaking are broadly classified as follows : Unalloyed, water-hardening carbon steels ; oil-hardening and air-hardening steels containing chromium and wolfram ; high-speed steels ; and sintered carbides. Their heat-treatment, rolling, forging, and welding are described.

Nine chapters cover the following types of tool : Drilling ; counter-sinking ; grinding ; broaching and reamering ; thread-cutting ; milling ; milling cutters with interchangeable cutter heads ; gear-cutting tools ; and cemented carbide cutting tools. Complete details of materials, types, designs, and applications of each kind of tool are furnished.

Finally, there is a chapter on the maintenance and care of tools. The photographs are excellent throughout. A useful index is included.—R. SEWELL.

SKAUPY, F. "*Metallkeramik.*" Fourth edition. 8vo, pp. 267. Illustrated. Weinheim/Bergstr., 1950 : Verlag Chemie, G.m.b.H. (Price DM 19.– or 31*s.* 3*d.*)

The first edition of this book appeared in 1930 and was the first general survey of 'metal ceramics' ever to be made ; it contained 60 pages. The author had played a prominent part in the original development of tungsten carbide at the Osram Studiengesellschaft in the 1920's, having been connected previously with the manufacture of tungsten filaments since 1907. He was, therefore, at that time in an admirable position to write an authoritative account of a comparatively unknown field of metallurgy.

Whilst the publishers are quite entitled to issue now a completely revised, fourth edition, it must be stated that this description is hardly in accordance with the facts. The so-called 'second' edition appeared in 1935 as a 10-page supplement. The 'third' edition was then published in 1943 in a much enlarged form. It included all the original 1930 material, but considered also in great detail the various important fundamental investigations that had been made during the 1930's by Trzebiatowski, Sauerwald, Balshin, Jones, and others. A careful scrutiny of the present 'fourth' edition reveals that the 1943 edition has simply been reset, admittedly more attractively, with the addition of some 20 insertions of any importance, *viz.*, pages 35, 39, 50–51, 75, 76, 92–94, 98–99, 110–111, 131–133, 144, 147, 159, 175, 196, 198, 200, 211–212, 222, 225, 229, 250. The transcription from one edition to the other is, indeed, so accurate that the Wiegener method of particle-size analysis by sedimentation that was called in 1930 "eine weitere und zwar gegenwärtig die wichtigste Methode" still appears as such in 1950 (p. 72). It is also surprising to read (p. 53) of a "neuere Arbeit" by A. E. Smith that appeared in *Metal Industry* for 1929. Numerous similar instances could be quoted.

The 1930 Introduction has been retained, with the addition of a somewhat lengthy bibliography, and a short chapter has been included on combinations of metal powders and refractory oxides.

It is not too much to say that the book covers neither the war-time period nor post-war developments. For instance, the chapter on iron powder metallurgy has been reproduced from the 1943 edition, with an additional two pages (pp. 211–212) on developments since 1940, but there is not even a mention of sintered-iron driving bands for shells. It is, of course, always possible that the German secrecy regulations were enforced so efficiently that the author really knew nothing of this quite remarkable development.

As a careful survey of pre-war powder metallurgy with a distinct academic bias, this book may be worth consulting, but judged by current standards and requirements in this country, it conveys a quite out-of-date picture of 'metal ceramics.'—R. A. HETZIG.

SOMMER, F., and H. POLLACK. "*Elektrostahlerzeugung.*" 8vo, pp. xii + 338. Illustrated. Düsseldorf, 1950. Verlag Stahleisen m.b.H. (Price DM 34.–)

The first electric steel furnaces were operated in 1906. The world now produces over ten million tons of electric steel. Electric steelmaking furnaces have developed from the two-electrode furnaces of 1½ tons capacity to 100-ton A.C. furnaces and the high-frequency furnace.

This book (another excellent one in the Stahleisen-Bücher series) was started in December, 1939, and was in draft form in 1944. The German and Austrian collapse prevented its publication, and when the authors turned again to their work in 1948, the question arose whether the book gave a true picture of the present position of electric steelmaking. In 1944, one of the authors had helped to put into operation one of the most modern electric steelworks in Europe, incorporating all the latest scientific experience. However, a subsequent study of the American Institute of Mining and Metallurgical Engineers Electric Furnace Proceedings for 1944 to 1948 convinced the authors that German developments had not lagged behind.

After surveying the development and the electro-technical and physical principles of the modern arc furnace, the authors deal with its refractories, constructional details, and electrical equipment. A similar study of induction furnaces is also made. The principles of refining and melting in acid and basic arc and induction furnaces are described.

The final chapter deals with the economics and efficiency of the electric furnace and includes an explanation of wages and costing systems.—R. SEWELL.

HOFF, H., and T. DAHL. "*Grundlagen des Walzverfahrens.*" (Stahleisen Bücher. Bd. 9). 8vo, pp. xi + 295. Illustrated. Düsseldorf, 1950: Verlag Stahleisen m.b.H. (Price DM 29.–)

The appearance of this book by Hoff and Dahl on the fundamentals of rolling follows closely on the heels of a similar book by Underwood. The latter, in "The Rolling of Metals," has examined exhaustively the theoretical and experimental information without going into details of the properties of the materials rolled. On the other hand, the book by Prof. Hubert Hoff and Dr. Theodor Dahl approaches the subject from a wider basis, but restricts itself to the more elementary theories of rolling covering the period in which these two authors were themselves actively engaged in rolling-mill research.

The book opens with a historical account of the development of rolling from Leonardo da Vinci to the present time. The subsidiary processes such as piercing, Pilgering, and tyre-rolling are included and the development of the direct casting and rolling of non-ferrous metals is described. This is followed by a discussion of casting and surface defects and their removal before rolling, together with the effect of rolling in consolidating internal blowholes and other such defects.

The authors then discuss, in separate sections, the properties of the various metals which are normally rolled, the correct heating technique for ingots and billets, the recrystallization of the billet during hot rolling, the effect of temperature on grain size, mechanical properties, and the anisotropy of the metal, together with considerations of heat-treatment and processing after hot rolling.

The cold-rolling process is also considered for each of the metals, and its effect on orientation and anisotropy, and the heat-treatment following cold rolling are discussed. The materials dealt with are iron, carbon steels and alloy steels, aluminium and its alloys, copper and its alloys, zinc, tin, nickel, silver, and gold.

The next section of the book deals with the elastic and plastic deformation of metals and indicates the basic properties of metals in relation to the deformation in rolling. The various criteria of plastic flow and the elementary concepts of slip lines in plane plastic deformation are described. The earlier methods for determination of the stress–strain curve are given and the authors follow much the same course as that of Underwood, although the latter has covered a much wider range of the published data. They also indicate the flow patterns of the material during rolling, but again they report only part of the published literature.

In the next section the rolling theories of Siebel, von Karman, and Ekelund are discussed. This section is disappointing. Orowan's general theory of rolling is dismissed in one line as "a more general and exact solution of the differential equation."

The spread of the material in hot and cold rolling and also the forward slip in their dependence on temperature, pass reduction, and thickness ratio are next examined; this is followed by theoretical and experimental considerations of roll force and roll torque. For the latter, only the lever-arm method is referred to. The effect of speed in hot and cold rolling is dealt with in some detail.

There are some remarkable omissions in this book. It is natural that a bias in favour of German papers should be found, particularly a bias in favour of work which the authors carried out in their now classical experiments, but it is surprising that some excellent work carried out in Germany itself receives no reference. For example, only the early paper of Emicke and Pachaly is referred to in the text and bibliography, whereas the later paper by Emicke and his collaborators at the Freiberg school is not mentioned, even in the bibliography.

The rolling-mill engineer will find this work of undoubted value, but he should bear in mind that some considerable advances have been made in the last ten years of which little or nothing is reported.—H. FORD.

NEW PUBLICATIONS

AMERICAN WELDING SOCIETY. "*Recommended Practices for Metallizing.*" Part IA. "*Metallizing Shafts or Similar Objects.*" Part II. "*Metallizing—Safety Precautions.*" 8vo, pp. iv + 22. Illustrated. New York, 1950: American Welding Society. (Price 75 cents)

AMERICAN WELDING SOCIETY. "*Recommended Practices for Salvaging Automotive Gray Iron Castings by Welding (Tentative).*" 8vo, pp. iv + 17. Illustrated. New York, 1950: American Welding Society. (Price 50 cents)

BABLIK, H. "*Galvanizing (Hot Dip).*" Translated by C. A. Bentley. Third Edition. 8vo, pp. xiv + 502. [Illustr.] London, 1950: E. and F. N. Spon, Ltd. (Price 70*s.*)

BARKER, C. H., jun. "*Industrial Materials Handling.*" Revised and rewritten by I. M. Footlik, C. F. Yarham, and J. F. Carle. 8vo, pp. 381. Illustrated. Cleveland, Ohio, 1950: Lincoln Extension Institute. (Price $4.75)

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ROSEN, C. "*Centrifugal Casting by the Cire Perdue Process.*" Pp. 204. Watford: The Bruce Publishing Co., Ltd. (Price 52*s.* 6*d.*)

SPIERS, H. M. "*Technical Data on Fuel.*" London, 1950: British National Committee, World Power Conference. (Price 25*s.*)

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JOURNAL OF THE IRON AND STEEL INSTITUTE

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Single Copies 10s. each

EDITORIAL AND ADVERTISEMENT OFFICES
4, Grosvenor Gardens, London, S.W.1
Telephone : SLOane 0061. Telegrams : Irosamente, Sowest, London

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VOL. 167 PART 2 PUBLISHED MONTHLY FEBRUARY 1951

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JAMES WHITE, D.Sc., Ph.D., A.R.T.C.

JAMES WHITE was born in Langholm, Dumfrieshire, in 1908. He was educated at Langholm Academy and at Dumfries Academy, and later at the University of Glasgow, where he graduated B.Sc., with first-class honours in Physical Chemistry, in 1931. He received a D.S.I.R. Research Scholarship in Metallurgy at the Royal Technical College, Glasgow, which was tenable from 1931 to 1933, when he received the Dr. James Mackenzie Prize of the College.

Dr. White became a Research Assistant in the Department of Metallurgy at the College in 1933, and in the following year he was awarded an Associateship, and was appointed Lecturer in Metallurgy. In this capacity, and later as the senior member of the staff of the Metallurgy Department, under Professor Hay, Dr. White carried out a large amount of research work and undertook ad hoc metallurgical investigations on behalf of the Ministry of Supply. He was responsible at various times for lecture and laboratory courses in Metallurgy and Refractories. During 1934 he provided the courses in Metallurgy and Fuel to the Engineering Students of Aberdeen University.

In 1935 Dr. White obtained the degree of Ph.D. of Glasgow University, and the degree of D.Sc. was conferred on him in 1939. On leaving the Royal Technical College in 1943 he was appointed Research Technologist at Messrs. General Refractories Ltd., Worksop, and later became Head of Research. In 1946 he was appointed to his present position as Senior Lecturer in Refractory Materials in the Metallurgy Department of Sheffield University.

Dr. White serves on many technical committees, concerned generally with refractories. They include committees of the British Iron and Steel Research Association, the British Ceramic Research Association (Chairman of the Testing Committee and the Electric Furnace Refractories Sub-Committee), the British Cast Iron Research Association (Chairman of the Joint Sand Testing Committee), the British Non-Ferrous Metals Research Association, the Inter-service Metallurgical Research Council, and the British Standard Institution.

Elected a Member of The Iron and Steel Institute in 1938, Dr. White held a Carnegie Scholarship in the two previous years and he was awarded the Andrew Carnegie Gold Medal in 1939 for his paper on "Equilibrium at High Temperatures in Systems Containing Iron Oxides." He was appointed an Honorary Member of Council of the Institute in 1950, during his term of office as President of the Sheffield Metallurgical Association. He was the first Chairman of the Refractories Group of that Association when it was formed in 1946. He is also a Member of the Councils of the Refractories Section of the British Ceramic Society and of the Refractories Association of Great Britain.

Dr. White's many published papers deal generally with the study of process metallurgy and of refractories from the standpoint of physical chemistry. He has also been responsible for many detailed contributions to discussions.

James White, D.Sc., Ph.D., A.R.T.C.

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